Barrier Island Plan

Phase 1 - Step K Report

Identification and Assessment of Management and Engineering Techniques

October 31, 1997

T. Baker Smith & Son, Inc.
DNR Contract No. 25081-95-02

PROJECT OVERVIEW

The barrier island plan is authorized by the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA). The purpose of this study is to determine whether the Louisiana barrier shoreline provides significant protection to Louisiana's coastal resources. If the study proves that the barrier shoreline provides these significant benefits, then this study will develop the most cost effective method to maximize those benefits.

The three year barrier island feasibility study is divided into three phases based on geographical location. Phase 1 is located between the Atchafalaya and Mississippi Rivers. Phase 2 encompasses the cheniere plain barrier formations in Vermilion and Cameron Parishes. Phase 3 focuses on the Chandeleur Islands. Phase 1 is the area currently being studied.

The project is structured to reach an implementation plan by starting from a broad descriptive analysis and gradually becoming more site-specific and detailed as the steps proceed. Each resource study or island option plan begins with some type of qualitative assessment and progresses to a more detailed quantitative analysis. For example: Step C will qualitatively focus on the status and trends of resources for the broad study area; whereas, Steps E and F will quantitatively assess and inventory the existing environmental and economic resources respectively. Also, Step I is a general evaluation of the needs and problems in the study area and development of management alternatives. Later, Step L will define the preferred plan criteria and chose a recommended implementation plan from the management alternatives developed in Step I, based on the quantitative assessments made in Steps J and K.

The first report completed for the barrier island feasibility study is Step A, which reviews prior studies, reports, and existing projects that pertain to the study's purpose, scope, and area. Step A also identifies and describes existing and potential barrier island and wetland restoration projects that affect the Phase 1 area. Step A is an overall orientation for the team on the project area. The literature review ensures that the team is knowledgeable and familiar with the most current literature available on the barrier islands and is using the most up-to-date information throughout the overall study.

Step B is also completed and contains a conceptual and quantitative framework for the barrier island study. The conceptual framework describes the functions and processes affected by barrier islands and the potential impacts on the significant resources in the study area. The significant resources include economic, cultural, recreational, and land-use resources. Step B also contains a review of the available methods for quantitatively predicting the effects of the barrier islands on environmental and economic resources. This information outlines the general study area for the team and describes the methodology that will be used in Step G to forecast physical and hydrological changes.

Step C provides qualitative assessments of the status and trends of the resources in the project area. A general study area map from Step B defines the area influenced by the barrier islands for the purposes of the Step C general resource assessment. These assessments include economic, social, cultural, water, biological, recreational, and land resources. In addition, the climatology, hydrology, and geological processes are analyzed with regard to their status and trends within the study area. Historical land losses are documented, as well as natural and human contributors to barrier island and wetland change. This information is gathered to demonstrate the characteristics of the study area and to show the resources at risk due to the loss of the barrier shoreline. It also orientates the team to the area and ensures the team will consider these resources in later steps.

Step D is a quantitative inventory of the physical parameters that are used to forecast changes in the economic and environmental resources. Step D involves delineating zones of environmental and economic analysis in the general study area described in Step B. The zones are designated using the Hurricane Andrew storm surge as criteria. The physical process parameters (waves, wind, sea level, sediment transport, etc.) and the geomorphic parameters (surficial sediments, topography, bathymetry) are identified, including data sources, type and quality of data, and any inconsistencies or "gaps" in the data. This information will be used as input for the modeling and forecasting effort in Step G. The results of Step D allow the team to evaluate the proposed modeling effort as outlined in Step B.

Step E provides a quantitative inventory and assessment of existing environmental resource conditions, with an emphasis on those resources considered significant. The team developed the criteria for determining "significant" environmental resources. Wildlife habitats, breeding grounds, and endangered species refuges are among those resources that have been assessed. Step E includes historical habitat/wetland change maps and describes the land loss rates and their associated changes. These data will be used to forecast the impact of the no-action scenario for environmental resources.

Step F is a quantitative inventory and assessment of existing economic resource conditions. This includes all structures, facilities, farmland acreage, and public resources (roads, channels, bridges, etc.) that are susceptible to the consequences of wetland/land loss, shoreline erosion, or hurricane induced flooding. The value of these economic resources and their residual worth will be included in the assessment. Historical damage and losses caused or induced by oil spills, waves, wetland/land loss, and shoreline erosion will also be evaluated. These data will be used to forecast the impact of the no-action scenario on economic resources.

The forecasted trends of physical and hydrological conditions will be discussed in Step G. A 30 year forecast of the present and future physical conditions will be modeled, showing the effects of a no-action scenario. The study will be conducted using the methods described in the Step B report and the data specified in the Step D report. Bathymetry and topography, waves, tides, storm surge, and other factors that affect the economic and environmental resources will be forecasted.

The effects on environmental resource conditions will be forecasted in Step H. Projected wetland/land loss will be presented for the 30 year no-action scenario. This will estimate, through the modeling results from Step G and projected trends, the total land loss and the effects on the wildlife that will be experienced within the thirty year period as present conditions proceed. At the completion of Step H, the team will have amassed information detailing the projected changes in the barrier shoreline and the anticipated effects of those changes on the environmental resources in the area. The team can then use this information as a baseline to compare other alternatives.

In Step I, the team begins to identify the options to be evaluated. This process will proceed through Steps J, K, L, and M. The later steps involve the identification and explanation of the preferred alternative(s). Step I involves identifying the problems, needs, and opportunities of the study area and developing strategic options. Options will be considered on an island-chain spatial scale. These options will include restoring a historical island configuration, establishing a fall back line, no-action alternative, preserving present-island configurations, strategic retreat, and other possible options. A general assessment of engineering, environmental, economic, and social factors regarding strategic option implementation will be considered. An array will be built comparing the different options with these factors. Those options that cannot be implemented because of cost, long-term effects, or other conditions will no longer be considered. The remaining options will become management alternatives and will be analyzed in greater detail in Step J. Step I will provide the necessary island size and inlet locations for the modeling study in Step J.

Step J is the assessment of management alternatives. The most important input for Step J is the identification of the specific management alternatives found in the Step I report. Step J includes qualitative and quantitative assessment of the management alternatives. This step includes a more detailed analysis of the effects of the proposed management alternatives on the environmental and economical resources of the area. For example, if a management alternative being investigated in Step J is a 1930 island configuration, then in Step J the increased flood protection potential from hurricanes by virtue of the size increase of the barrier islands will be described. That protection estimate will be an approximate dollar estimate and not a general assessment as was done in Step I. The output for Step J will be a detailed assessment of the effects of the management alternatives on the resources in the area. Resources include environmental, economical, and social. Where possible, the effects on resources will be quantified. The report should be based on a thirty year projection into the future and compared to the no action scenario.

Step K involves identifying and assessing possible management and engineering techniques for the management alternatives developed in Step I. Step K assesses the engineering techniques that may be used to implement the management alternatives identified in Step I. The long-term impacts will be used to assess the effectiveness of the various engineering and management techniques. This step will determine possible use of beach fill, coastal structures, and possible regulatory controls that will provide optimal design life and cost effectiveness. Dune crest height and berm and beach slopes will be determined for limiting wave runup and overtopping. Volumes of beach fill will be calculated after the beach and dune configurations are established. In addition, borrow site identification and assessment will be completed. This will determine the cost, quantity available, and methodology for using various borrow sites for material if needed. The output for Step K will be the general applicability, cost, and impacts of various engineering alternatives.

Step L will be a description of the rationale for selecting a preferred plan. The criteria will be based upon the detailed assessments made in Steps J and K to develop a cost/benefit relationship. Step J will supply the benefits for each management alternative, while Step K details the cost. The selected management alternative and associated engineering and management techniques will be developed to form preliminary plans and cost estimates. Included will be all beach fill and coastal works concepts, sources of material, and cost of maintenance and monitoring.

In Step M, the team will select the preferred plan based on the criteria described in Step L. The team will then describe the methodology for instituting permitting, right-of-way/construction agreements, final engineering design, bidding, construction, mitigation, monitoring and maintenance. The preferred island configuration will be presented with potential structures, beach fill, dune restoration, and protection plans. Preferred sand sources and the effect of removing the sand will also be detailed. The Step M report will outline time, cost, and regulatory parameters.

Step N is a consolidation of all deliverables into one final report document. This final report will summarize the information provided in all previous documents.

FOREWORD

The purpose of this study is to assess the consequences to the coastal resources in the Phase 1 Study Area if the barrier shoreline is allowed to continue deteriorating. Also, the study team is tasked to develop barrier shoreline alternatives that will protect and enhance coastal resources.

To achieve these goals, the study has completed the following reports:

Phase 1 - Step A	**A Review of Pertinent Literature**
Phase 1 - Step B	**Conceptual and Quantitative System Framework**
Phase 1 - Step C	**Assessment of Resource Status and Trends**
Phase 1 - Step D	**Quantitative Inventory and Assessment of Physical Conditions and Parameters**
Phase 1 - Step E	**Inventory and Assessment of Existing Environmental Resource Conditions**
Phase 1 - Step F	**Inventory and Assessment of Existing Economic Resource Conditions**
Phase 1 - Step G	**Forecasted Trends in Physical and Hydrological Conditions**
Phase 1 - Step I	**Forecasted Trends in Formulation and Assessment of Strategic Options**

The Step K Report is an Identification and Assessment of Management and Engineering Techniques in the Phase 1 Study Area. The management alternatives, defined and qualitatively assessed in Step I, will be evaluated in Step J to quantify the benefits provided for each alternative. In Step K, the cost to implement and maintain each alternative will be evaluated. Also, sources of material and a description of the construction techniques will be described and evaluated. Hard and soft structure techniques for building and maintaining the barrier shoreline will also be discussed.

The following team members have contributed to this part of the study:

T. Baker Smith & Son, Inc.

Wm. Clifford Smith, P.E., P.L.S.
Marc J. Rogers, Sr., P.E.
Stephen Smith, J.D.
Stephen Gilbreath, M.S.
Donald W. Davis, Ph.D.

Coastal Engineering and Environmental Consultants, Inc.

Oneil P. Malbrough, Jr., REM
Subrata Bandyopadhyay, Ph.D.

Murali M. Dronamraju, Ph.D., MBA

Applied Technology Research Corporation

Lawrence S. McKenzie, III, M.S.

Lorna Guynn

Louisiana State University

Randolph A. McBride, M.S.

Denise J. Reed, Ph.D.

Gregory W. Stone, Ph.D.

Joseph N. Suhayda, Ph.D.

Bruce A. Thompson, Ph.D.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

The Phase 1 Study Area extends from the Mississippi River to the Atchafalaya River. With respect to the barrier shoreline, the western boundary is Raccoon Island and the eastern boundary is Sandy Point. Following the same format used in Step I, the study area was divided into four sub-areas: 1) Isles Dernieres, 2) Timbalier Islands, 3) Caminada-Moreau Headland/Grand Isle, and 4) the Plaquemines shoreline.

The Phase 1 barrier shoreline is one of the most highly erosive areas in Louisiana, as well as the United States. Many factors such as subsidence, lack of sediment in the system, sea-level rise, and deteriorating beach and dune systems have contributed to the progressive degradation of the barrier shoreline. Despite continued erosion, the barrier shoreline still serves as a storm barrier and a defining entrance into the estuaries. Also, barrier islands provide natural erosion protection for landward areas (Adams *et al.* 1978). The islands dampen waves and define the lateral boundaries of the conduit of saltwater into the estuaries. A feasibility study on the Grande Terre Islands completed by the Corps of Engineers (USACE 1988) stated:

> "The barrier islands and barrier beaches form an effective buffer between the Gulf of Mexico and the coastal marshes and communities of the Barataria Basin. These coastal barriers absorb and dissipate much of the wave energy and flooding effect of storm tides generated in the gulf. Communities as far as 40 miles inland from the coast benefit from hurricane and storm surge reductions that can be directly attributed to the presence of the barrier islands. Loss of barrier islands and barrier beaches will allow higher hurricane and storm stages at locations farther inland from the coast."

The purpose of this study is to quantify the changes in resources for the entire Phase 1 Study Area. The coastal resource benefits of the two management alternatives and no-action alternative were quantified in Step J - Assessment of Management Alternatives. The Step K report focuses on the initial and maintenance costs to implement the two alternatives evaluated in Step J. By quantifying the average annual cost of a project, a management plan can be developed to maintain that project using an economically and ecologically beneficial maintenance option. This report evaluates the use of building up the island with sand, while utilizing maintenance options ranging from: 1) beach and dune renourishment, 2) use of breakwaters and groins with beach and dune renourishment to reduce maintenance costs, and 3) constructing a rock revetment along the entire gulf shoreline with no beach or dune renourishment.

Section 2.0 provides a general description of coastal processes relating to coastal engineering at the barrier islands. Much of this section has been taken from Step D (Quantitative Inventory and Assessment of Physical Conditions and Parameters). Section 3.0 discusses potential borrow areas that have been identified and evaluated to determine which sources are most cost effective and contribute to the overall needs of the system.

Next, Section 4.0 contains a description of the alternatives and the preliminary design process. Section 5.0 contains a summary of initial, maintenance, and annual project costs. Section 6.0 describes the long- and short-term impacts directly related to each engineering technique.

The Step K report refines the conceptual alternatives that were developed in Step I - Formulation of Strategic Options. The two alternatives from Step I, described below, will be refined and evaluated using: 1) three different dune heights associated with different return period water levels, 2) soft structure (sand only) maintenance, 3) dune and hard structure maintenance, and 4) combinations of soft and hard structure maintenance. Evaluating the alternatives using combinations of dune heights and maintenance plans demonstrates the incremental costs and benefits associated with each.

Alternative 1

Alternative 1 begins at the western end of the study area with wave absorbers along the marsh shoreline. The wave absorbers begin at the mouth of Bayou Grand Caillou, paralleling the marsh shoreline to the southeast, ending due north of Whiskey Island's west end. Whiskey Island is included in Alternative 1, and Whiskey Pass is closed. New Cut is also closed, making Whiskey, Trinity, and East Islands one continuous island. Wine Island Pass is left open, but Wine Island is expanded. The islands are constructed with a dune height of ±2.7 m (9.0 ft), and an overall width of ±600 m (1,970 ft).

A second line of wave absorbers begins north of Wine Island Pass in Lake Pelto at the marsh fringe. This line of wave absorbers follows the southern end of Lake Barre and Lake Raccourci, down to Pierle Bay in the southeast corner of Timbalier Bay.

Cat Island Pass remains open, and Timbalier Island is rebuilt. Little Pass is left open, and East Timbalier Island is rebuilt and connected to the Caminada-Moreau Headland, closing Raccoon Pass. The islands are rebuilt to the same specifications as the Isle Dernieres chain.

The Caminada-Moreau Headland and Grand Isle area are rebuilt to a dune height of ±2.7 m (9.0 ft), but do not widen the existing shoreline. The Plaquemines shoreline is rebuilt to the same specifications as the Isle Dernieres and Timbalier sections, but Barataria Pass, Coup Abel, Quatre Bayou Pass, and several smaller passes are left open. Alternative 1 is shown in Figure 1.

FIGURE 1-1. BARRIER ISLAND PLAN MANAGEMENT ALTERNATIVE #1

Figure 1.Barrier Island Plan Management Alternative 1

Alternative 2

At the western end of Isle Dernieres, Raccoon Island is rebuilt and reconnected to Whiskey Island by closing Coup Colin. Whiskey Pass is left open, with Trinity and East Island connected due to the closure of New Cut. These islands are built with a dune height of ±2.0 m (6.6 ft), and an overall width of ±375 m (1,230 ft).

Cat Island Pass is left open and Timbalier Island is rebuilt. Little Pass is left open, and East Timbalier Island is rebuilt and connected to the Caminada-Moreau Headland by closing Raccoon Pass. These islands are rebuilt to the same specifications as the Isle Dernieres chain.

The Caminada-Moreau Headland and Grand Isle are also rebuilt to the same specifications as the Isle Dernieres chain. At the Plaquemines shoreline, Barataria Pass, Coup Abel, Quatre Bayou Pass, and several smaller passes are left open. This area is also rebuilt to the same specifications as the other island chains. Alternative 2 is shown in Figure 2.

FIGURE 1-2. BARRIER ISLAND PLAN MANAGEMENT ALTERNATIVE #2

Figure 2.Barrier Island Plan Management Alternative 2

A list of terms used in the report was derived from *Design of Beach Fills* (USACE 1995). The reader should refer to these for clarification when necessary.

LIST OF TERMS (From USACE 1995, EM 1110-2-3301)

Accretion - Natural or artificial buildup of land by the deposition of sediments.

Advanced Nourishment - Placement of an additional amount of beach fill to offset the expected losses from the time of completion of the project to the first scheduled nourishment event.

Back Barrier - Pertaining to the lagoon complex in the lee of a coastal barrier island, barrier spit, or baymouth barrier.

Barrier Island - An elongated island running parallel to the mainland coast separated from the mainland by a lagoon or bay.

Beach Fill - Material placed on a beach to renourish eroding shores.

Beach Nourishment - Process of replenishing a beach with material (usually sand) obtained from another location.

Beach Renourishment - Process of replenishing a beach. It may be brought about by material longshore transport or artificially by the deposition of borrowed material.

Beach Slope - Degree of inclination of the beach to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating 1 unit of vertical rise in 25 units of horizontal distance. Also expressed in a decimal fraction (0.04), degrees (2°18'), and percent (4%).

Berm - Nearly horizontal part of the beach or backshore formed by the deposit of materials by wave action. Some beaches have no berms and others have one or more.

Berm Crest - Seaward limit of the berm.

Borrow Material - Material used for placement of artificial beach nourishment.

Construction Template - Template defining the shape of the fill profile at the time of fill placement.

Cross-Shore Transport - Movement of beach material perpendicular to the shore by waves and currents.

Depth of Closure - Depth beyond which sediments are normally affected by waves.

Design Template - The shape that fill material is expected to achieve after being worked by waves over the first few months to a year after fill placement. The design profile may be based on the pre-fill profile shape if the fill material is similar to the original native beach material.

Detached Breakwater - A structure detached from the shore constructed to protect a shore area, harbor, anchorage, or basin from waves.

Downdrift - Direction in which littoral drift is moving.

Dune - Hill or mound of windblown material, usually sand.

Dune Base - The toe of the dune on the seaward side.

Dune Crest - Highest elevation associated with a dune system.

Equilibrium Profile - Response of a beach to long-term or extreme wave conditions governed primarily by sediment size characteristics.

Erosion - Removal of sediment by the action of natural forces.

Inlet - A connecting passage between two bodies of water.

Littoral Drift - Movement of sediment alongshore. Also, the material being moved alongshore.

Littoral Transport - Movement of littoral drift in the littoral zone by waves and currents. Includes movement parallel (alongshore) and perpendicular (Cross-shore) to the shore.

Longshore Transport - Transport of littoral sediments by a current flowing essentially parallel to the shoreline, usually generated by waves breaking at an angle to the shore line.

Maximum Net Benefits - Difference in damages to a project area between without-project and with-project conditions.

Median Grain Size - Diameter of sediment that marks the division of a grain size sample into two equal parts by weight.

Nearshore - Indefinite zone extending seaward from the shoreline well beyond the breaker zone.

Overfill Ratio - Volume of borrow material required to produce a stable unit of usable fill material with the same grain size characteristics as the native material.

Periodic Nourishment - Periodic placement of artificial beach fill for replenishing a beach.

Renourishment Factor - Technique used to predict how often renourishment will be needed using the selected borrow material.

Runup - Rush of water up the face of a structure or beach due to waves.

Significant Wave Height - Average height of the highest one third wave in a wave group.

Tidal Current - Currents created by the propagation of tides through coastal areas which cause water surfaces gradients and currents.

With Project - Estimate of damages after construction for a coastal project.

Without Project - Estimate of damages that would occur in the absence of a coastal project.

2.0 COASTAL PROCESSES

2.1. Hydrodynamics

2.1.1. Wave Climate

Waves are the major mechanism for determining the shape and composition of a beach. Therefore, it is imperative that a fundamental understanding of wave processes be achieved. Waves and their interaction with beaches is a complex process, of which scientists and engineers have limited understanding. The purpose of this section is to educate the reader in the general concepts regarding wave theory and to relate these concepts as to their effects on the beaches.

Waves are generally produced by wind transferring energy into the sea surface. Wind creates a force on the surface which activates gravitational and surface tension forces allowing the wave to propagate, similar to the tension on a string causing it to vibrate (Dean and Dalrymple 1984). Once produced, waves travel across the waterbody until they reach land, where their remaining energy is expended on the shore (USACE 1984).

Waves can be produced in bays, lakes, and lagoons, as well as in the ocean. The distance wind blows over the water surface is called “fetch”. Long durations of wind blowing from a particular direction, stronger wind speeds, and/or greater fetch will produce larger wave heights (Traverse 1988).

Figure 3 illustrates the basic components of a simple sinusoidal wave. Waves are generally described by their length (L), height (H), and the water depth over which they are propagating (Dean and Dalrymple 1984).

In deep water, water particles in the waves travel in a circular pattern. As the wave moves into shallower water, interaction with the bottom causes water particle motion to move in a more elongated pattern. Generally, as waves move from deeper to shallower water, the waves slow down and the wave height peaks. Thus, the waves become steeper since the wave period remains constant.

Most nearshore regions have an irregular bathymetry due to irregular nearshore bars or variations in the beach slope along the shoreline. As the waves move into these irregular bathymetric areas, the wave celerity changes accordingly. Waves in deeper water travel faster than those in shallow water and, therefore, bend parallel to bathymetric contours. This bending of waves is known as refraction and plays a significant role in wave height and energy distribution, which contribute to erosion and deposition of beach materials.

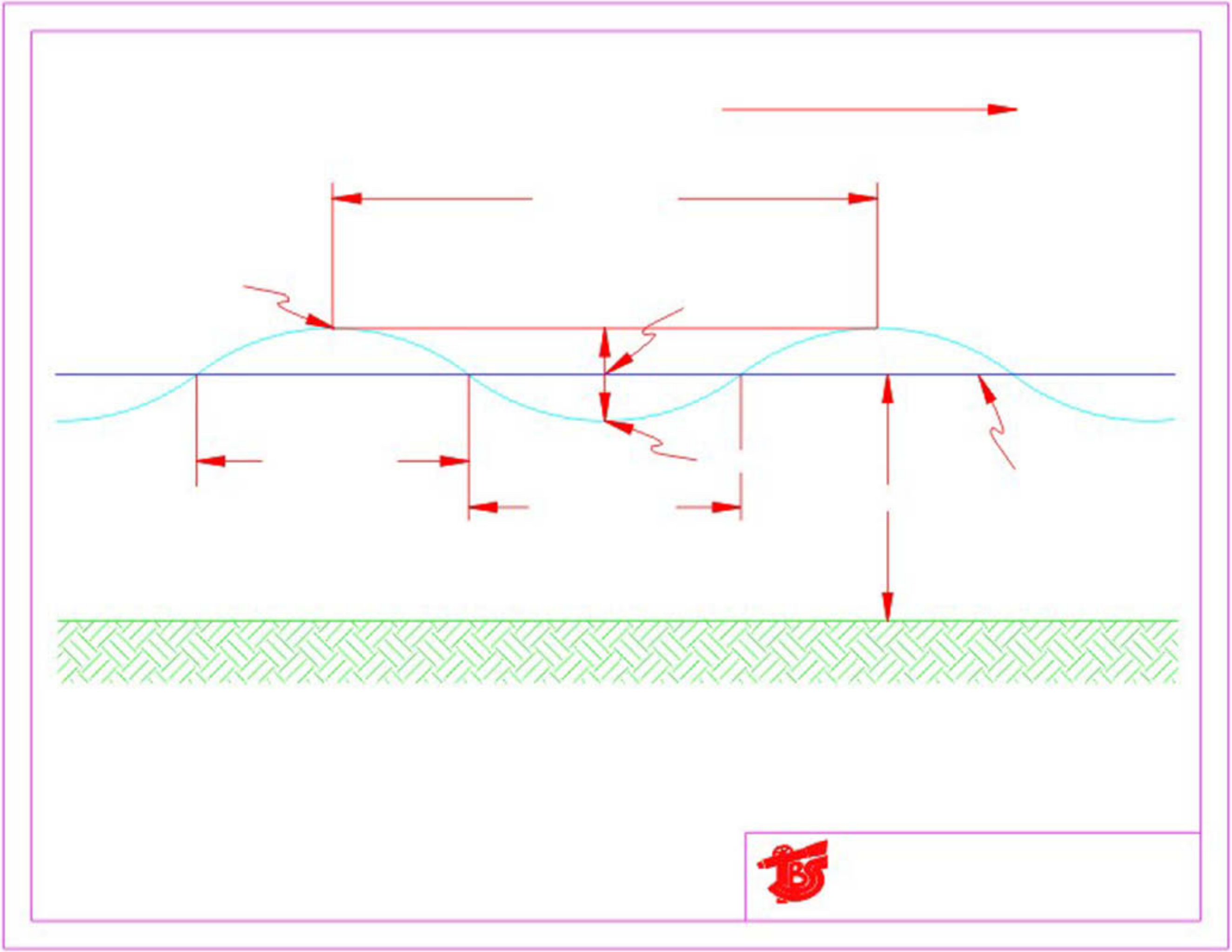


Figure 3.Wave Characteristics

As waves proceed to the shore and water depths become shallower, wave height begins to increase and wavelength decreases, producing a steeper wave. As the wave continues moving into shallower depths, the wave crest velocity becomes greater than that of the deeper areas of the wave. Eventually, the wave becomes unstable and breaks. Much of the wave energy is dissipated in the breaking process.

For mild sloping beaches, such as those along the Louisiana coastline, the breakers are called spilling breakers. A beach with a steeper slope (winter profile) will allow waves to break closer to the shore as opposed to a beach with a gentler slope (summer profile). A simple rule developed by McCowan (1894) states that waves break when they reach a certain fraction of the water depth in relation to the wave height:

$$H_b = d_b \kappa$$

where H_b = breaking wave height, κ = 0.78, and d_b = depth of wave breaking. More elaborate predictive solutions are available, but will not be discussed in this report.

In the Phase 1 Study Area, the significant wave height (H_S = average of the highest one-third waves) is approximately 1.0 meters (3.3 ft.) (BSFS Steps D and G). Nearshore wave measurements are lacking in the study area. Therefore, an offshore wave refraction model (STWAVE) using data from the Wave Information Study (WIS), the National Data Buoy Center (NDBC), and the Louisiana-Texas Shelf Physical Oceanography Program (LATEX) was used to generate and measure nearshore waves as they would occur along the islands and in the bays (Step G and J).

The offshore WIS data showed an annual mean wave height from 0.8-1.2 m (2.6-3.9 ft) and a mean peak period of 4.5-6.0 seconds. NDBC offshore data showed the monthly mean significant wave height to be 0.8-1.4 m (2.6-4.6 ft) with mean peak periods from 4.3-4.9 seconds. LATEX data showed monthly mean wave heights from 0.3-1.3 m (1.0-4.3 ft) and a period from 5.5-6.0 seconds. The dominant direction of the waves is from the southeast.

The height and angle of breaking waves are often used to quantify the longshore sediment transport rates. Wave steepness (H/L) is used to quantify cross-shore movement of sediment. Longshore transport is a wave-induced current that moves sediment parallel to the shoreline, while cross-shore transport moves material perpendicular to the shoreline. Littoral transport will be discussed in more detail later in the report.

2.1.2 Water Levels

Changes in water level can be produced by astronomical tides, storm surge, wind, subsidence, and eustatic sea level rise. All these factors contribute to the relative shoreline recession and allow wave energy to erode or deposit sand along the gulf and bay shorelines.

2.1.2.1. Astronomical Tides

Tides are the periodic rising and falling of sea level caused by the gravitational attraction of the planets, moon, and sun acting on the earth (USACE 1995). The astronomical tides in the Gulf of Mexico are diurnal with an average range of 0.3 m (1 ft) (Marmer 1954; Zetler and Hansen 1970). Nearshore tides have an average range that increases slightly from east to west across the Phase 1 study area. The title ranges for different locations within the study area are shown in Table 1.

Table 1. Yearly variation in the monthly high tide elevation. (Highest Tide, Ft NGVD)

	Southwest Pass	**Barataria Pass**	**Timbalier Island**	**Wine Island**	**Raccoon Point**
January	1.5	1.4	1.4	1.5	2.0
February	1.4	1.3	1.3	1.4	1.8
March	1.5	1.4	1.4	1.5	2.0
April	1.5	1.4	1.4	1.5	2.0
May	1.7	1.6	1.6	1.7	2.2
June	1.9	1.7	1.7	1.9	2.5
July	1.9	1.7	1.7	1.9	2.5
August	1.9	1.7	1.7	1.9	2.5
September	1.9	1.7	1.7	1.9	2.5
October	1.9	1.7	1.7	1.9	2.5
November	1.8	1.7	1.7	1.8	2.3
December	1.6	1.5	1.5	1.6	2.2

2.1.2.2 Sea-Level Change/Subsidence

Sea-level change is discussed in greater detail in the BSFS Step D report. Studies show that the average relative sea-level range in the deltaic plain is 1.0 cm/yr (0.4 in/yr) (Ramsey *et al.* 1991). EPA has estimated that global sea-level rise is currently 0.23 cm/yr (0.09 in/yr) and estimates that the rate will increase to 2.5-3.2 cm/yr (1.0-1.3 in/yr) in the next century (Titus 1988).

EPA estimates that a 30 cm (1 ft) rise in sea-level translates into at least 30 m (98 ft) of sandy beach erosion along the Gulf Coasts (Hoffman *et al*. 1983). As sea-level rises, waves attack and erode more of the landward beach. During calm conditions, sediment is redeposited onto the beach by smaller, less steep waves. However, as sea-level continues to rise, less of the material deposited offshore can redeposit back onto the beach. As water depth increases, the closure depth continues to translate towards the shoreline, reducing the capability of calm conditions moving some material back to the beach.

2.1.2.3. Storm Surge

Storm surge is the rise in water level due to the combined differences of atmospheric pressure and shore-normal wind (Traverse 1988). Elevated coastal waters allow storm waves to propagate further inland, thus subjecting beaches and structures to wave forces not ordinarily experienced. Surges, and the associated storm waves, are responsible for most damage to coastal areas (USACE 1989). More than anything else, storm surge causes breaching and overwash of the barrier islands. From a human resource perspective, hurricane surge alone accounts for three-fourths of the lives lost from hurricanes (USACE 1972).

When a tropical storm or hurricane enters an estuary or bay, it will generate a surge that acts similar to an astronomical tide. The amount of water transported into the estuary depends on the size of the inlet, whether the storm has overwashed low-lying areas such as barrier islands, difference in heads between the two water bodies, and the duration of the disturbance. The surface elevation (surge height) is dependent on the amount of water transferred from the sea, basin geometry, wind speed and direction, length of wind fetch, rainfall, rainfall runoff, and water input from rivers (USACE 1986).

Hurricane return periods were computed for Grand Isle by the Corps (USACE 1972) using observed and synthesized data. The results are shown in Table 2. These frequency curves have not been updated by the Corps to include more recent hurricanes. However, the more recent storms are estimated to have little effect on the stage-frequency values reflected here.

Table 2. Stage-Frequency for Grand Isle (USACE 1972)

Frequency	Stage (feet)
Probable Maximum Hurricane	17
Standard Project Hurricane	9.9
100-year Return Frequency	9.3
50-year Return Frequency	8.5
20-year Return Frequency	6.7
5-year Return Frequency	3.0

Greenhill Petroleum Corporation consulted Dr. Joe Suhayda (LSU) to develop an operational design for their oil and gas facilities at East Timbalier Island. In the process, a hurricane surge exceedance statistical curve for East Timbalier Island, similar to that shown in Table 3, was developed. These water level data will be used in the design levels for the Barrier Island Plan.

Table 3. Stage-Frequency for East Timbalier Island (Suhayda 1991)

Frequency	Stage (feet)
200-year Return Frequency	17
100-year Return Frequency	14
50-year Return Frequency	11
20-year Return Frequency	7.1
5-year Return Frequency	1.0

2.2. Littoral Transport

Littoral transport is the movement of sediment in the littoral zone by waves and currents (USACE 1984). Littoral transport can effectively erode or deposit material at a location depending on the magnitude and direction of the waves and current.

The littoral zone encompasses the area from the shoreline to a depth offshore including the active profile or closure depth (USACE 1995). The closure depth is defined as the minimum water depth at which no measurable or significant change in bottom depth occurs (Stauble *et al.* 1993). Hallermeier (1981) used laboratory and field tests to determine that this depth is a function of the wave height that is exceeded 12 hr/year. The determination was then statistically simplified using the following equation:

$$H = 1.5H_{S_{0.137}} = 6.75H_S$$

H = annual depth of closure (m)
H_S = mean annual significant wave height (m)

For the Phase 1 study area, H_S = 1.0 m (3.3 ft); therefore, the annual depth of closure would be approximated to be 6.75 m (22.1 ft). After reviewing the List *et al.* (1994) profile data, this depth is considered too large. The profiles at the Isles Dernieres were compared to data collected in the 1880's, 1930's, and 1980's. Little translation occurred beyond 4.0 m (13.1 ft) water depth. Using the methods described by Kraus and Harikai (1983), the closure depth is estimated to be 4.5 m (14.8 ft). This is based on the marked decrease in standard deviation between the changes in List's profile depths. For this analysis, the closure depth is assumed to be 4.5 m (14.8 ft).

2.2.1. Longshore transport

As the waves move into the nearshore, they can be divided into two directional components, each causing nearshore sediment movement. The component moving material parallel to the shoreline is caused by the longshore current. The movement of material perpendicular to the shoreline is caused by the cross-shore current.

The longshore current is created by wave components that obliquely travel towards the shoreline. As waves refract in the nearshore due to bathymetry, they maintain an angle between the wave crest and the shoreline. When the waves reach their depth of breaking, energy is transferred in the direction of the breaking wave. The energy is transferred to the beach and nearshore sediments, creating a longshore current. Longshore currents carry eroded material away from the shoreline in the direction of pre-dominant winds and waves. The sediments carried in the longshore current come from rivers, local erosion, and inlets. Collectively, these sediments are called the littoral drift. The size and direction of the waves determine the magnitude and direction of the longshore current.

The physical transport of sediment may occur as suspended- and/or bed-loads. Both forms of transport are usually present at the same time. Suspended-load transport occurs when sediments are moved throughout the water column after being lifted from the bed by turbulence (USACE 1984). Material transported as suspended loads is usually the size of silt or clay, as sand tends to fall rapidly after it is suspended. For simplicity, it is assumed that suspended-loads consist of silt and clay.

Bed-load transport is the movement of sediments along the bed due to shear from water moving above the bottom surface (USACE 1984). The volume rate of flow of the longshore current is most sensitive to breaking wave height. Suspended load rarely affects the capacity of littoral currents compared to bed-load. Therefore, longshore transport is generally a function of bed-load transport, while suspended load transport removes fine-grained materials and deposits them in deeper waters (Traverse 1988).

2.2.2. Cross-shore transport

Cross-shore (onshore/offshore) transport is the movement of material perpendicular to the shoreline by waves and currents. For this discussion, cross-shore transport is divided into three classifications: 1) storm-induced, 2) seasonal profile changes, 3) beach fill profile adjustment, and 4) overwash.

Storm induced erosion occurs when waves and water levels increase due to storms, fronts, and hurricanes. As water levels increase, areas that are subaerial beaches under fair-weather conditions become submerged. Wave heights also increase as a result of increased winds. The result is increased erosion on the beach due to higher wave energy acting on more area of the beach. Sediment is removed from the nearshore and foreshore and is deposited offshore.

Removal of the sediment from the nearshore creates a “storm” profile that is steeper than the fair-weather shape. As wave heights decrease during the end of a storm, waves transform from erosive to accretive and the foreshore begins to rebuild. Prolonged periods of fair-weather conditions allow material deposited within the depth of closure to return to the nearshore to transform the storm profile. The erosion and recovery processes take place at very different rates. Storm erosion can take place in a matter of days, while recovery may take several summer cycles. Beaches are, therefore, very susceptible to damage from back-to-back storms where little time is available for recovery (USACE 1984). Under extreme events, sediment may be transported to offshore locations where it cannot be recovered in less severe conditions (USACE 1995). In the case of the barrier islands, material may also be lost due to overwash, either through sand movement to the back of the island, over the top of the dunes, or through newly developed inlets.

Seasonal changes also change the profile shape, creating winter and summer profiles. Winter storms create steeper waves that typically erode portions of the nearshore and deposit the material offshore in a longshore bar. Conversely, summer waves are milder and less steep. This induces onshore movement of sediment toward the shoreline producing a milder sloped beach than found during the winter.

If a beach fill is constructed, a disruption in the natural profile of the nearshore is created. Wave action will immediately begin to reshape the profile to a natural shape or "equilibrium" profile. Beach profiles develop a characteristic parabolic shape based on sediment characteristics. This concept is called the "equilibrium profile" and proposes that beach profiles maintain a parabolic shape based on sediment characteristics (Bruun 1954; Dean 1977; Dean 1991). If a new profile is introduced as the result of a beach fill, the material will be dispersed both alongshore and cross-shore. The cross-shore change is dependent on the depth of closure, the berm height, and the differences in the native and borrow material grain sizes. The equilibrium concept will be described further in the design section.

Overwash is another form of cross-shore sediment transport that occurs during storm events. Overwash is defined as a unidirectional flow or pulse of sediment-charged water, derived from wave action and storm surge, which results in the overtopping or breaching of coastal barriers (Schwartz 1975; Fisher and Simpson 1979). Water level variations result from storm surge, wave setup, wave runup, and the astronomical tide that together produce a potential overwash elevation that varies alongshore. Washovers occur where the water level elevation exceeds some threshold level. The extent of associated sediment transport and deposition is determined by barrier height, barrier width, and barrier permeability (inlet spacing). A primary control is the relationship between barrier height and overwash elevation. Barrier width controls washover dimensions by frictional dissipation as overwash traverses the barrier. In addition, barrier shoreline orientation in relation to dominant wave approach plays a critical role in the type of overwash and shoreline behavior. Barrier headlands and islands west of the Mississippi delta are oriented almost perpendicular to the dominant southerly wave approach, a factor that favors shore-normal sediment transport (overwash and inlet formation) over longshore transport (Boyd and Penland 1981).

Boyd and Penland (1981) report that such low-profile shorelines are less likely to experience channelized breaching and inlet formation. They estimate that the regional overwash threshold is 1.42 m (4.7 ft) above mean sea level, which is reached an average of 15 times per year, most frequently during cold fronts (October - April). The overwash threshold most dramatically occurs as a result of tropical storms and hurricanes with return frequencies of once every four years during the months of June through October. This analysis suggests that more than 70 percent of the barrier shorelines within the study area are overwashed at least once every year because berm/dune elevations are so low (<1.5 m (<5 ft)). Grand Isle, with an average elevation of more than 2 m (6.6 ft), is notable as the exception. An inventory of the barrier shoreline elevations is shown in Table 4.

Table 4. Barrier Elevation Along the Louisiana Coast (revised from Boyd and Penland 1981).

Barrier Shoreline	Less Than 1m (%)	1m - 1.5m (%)	1.5m - 3m (%)	Greater than 3m (%)
Isles Dernieres	33.6	66.4	0.0	0.0
Timbalier Islands	17.4	50.0	32.6	0.0
Caminada-Moreau Coast	46.7	32.0	21.3	0.0
Grand Isle	1.0	8.9	90.1	0.0
Grande Terre - Bastian Bay	16.0	84.0	0.0	0.0

Table 4 shows that in 1981, all of the Isles Dernieres and Plaquemines shoreline would be susceptible to overwashing from *minor* fronts. In comparison, 67% of the Timbalier Island, 79 % of the Caminada-Moreau Headland, and only 10% of Grand Isle would be overwashed by the lower water levels associated with fronts. The intensity of frontal systems is less than hurricanes, but the higher frequency of the fronts causes considerable erosion.

2.3. Historical Shoreline Change

Historical shoreline change for the Phase 1 Study Area was derived exclusively from Williams *et al.* (1992). Specifically, the long-term (≈100 years) rates are discussed in this report. The historical (100-year) shoreline change rates were used in the “future without project” (Step G report) prediction to determine the fate of the shoreline in 30- and 100-years. Long-term datasets allow engineers and planners to analyze shoreline changes that include *all* event- and non-event specific changes.

2.3.1. Isles Dernieres

The Isles Dernieres chain is a highly dynamic barrier island, which experiences erosion on both the gulf and bay side shorelines. These islands are low in elevation and thus, are overwashed frequently. The continual narrowing of the island between the gulf and bay shorelines has allowed overwashed sediments to be lost to the bays. The Isles Dernieres are divided into five areas from east to west: Raccoon Island, Whiskey Island, Trinity Island, East Isle, and Wine Island. In 1853, the barrier island arc was a continuous shoreline (Williams *et al.* 1992). Since then, the combined effects of high- and low-frequency events, relative sea-level rise, and lack of updrift sediment has disconnected the islands.

The Isles Dernieres have a historical gulf shoreline erosion rate of -11.1 m/yr (36.4 ft/yr) between 1887 and 1988. At the same time, the bayside shoreline has eroded at -0.6 m/yr (2.0 ft/yr) (Williams *et al.* 1992). The islands, therefore, are converging instead of migrating to counter the effects of sea-level rise. The islands are widest in the middle and become narrower at the ends. Except for the eastern East Isle dunes, the entire Isles Dernieres chain is experiencing convergence from both gulfside and bayside erosion. As shoreline narrowing continues, the island weakens and becomes more susceptible to breaching. High relative sea-level rise rates and inadequate sediment supply prevent these breaches from closing. Over time these breaches become larger and act as sinks for sediment moving in the littoral zone (McBride *et al.* 1995; see List *et al.* 1994). Over the last 100 years, the islands have been reduced from 3,532 to 771 ha (8,728 to 1,905 ft), thus making the Isles Dernieres one the most rapidly eroding barrier shorelines in the United States (Williams *et al.* 1992).

2.3.2. Timbalier Islands

The Timbalier Islands consists of Timbalier and East Timbalier Islands. Timbalier Island is dominated by wind and wave processes. This is evident in the lateral migration of Timbalier Island at a historical rate of 80 m/yr (262 ft/yr). Portions of Timbalier Island are wide enough to prevent overwash materials from being transported across the island and into the bay. This allows material to accumulate on the western end, thus allowing lateral migration. Meanwhile, East Timbalier Island was an overwash dominated island where the acreage actually increased from 93 to 495 ha (230 to 1,223 acres) between 1934 to 1978. Since then, the island has become fragmented and has deteriorated within the boundaries of the seawall placed around it (Williams *et al.* 1992).

Between 1887-1988, the Timbalier Island’s gulf shoreline has eroded -15.2 m/yr (49.9 ft/yr), while the bay shoreline has migrated landward 11.7 m/yr (38.4 ft/yr). The landward migration of the Timbalier Islands is solely due to the historical landward migration of East Timbalier Island. Recent rates (1978-1988) suggest this has stopped. Therefore, both islands in the sub-area will experience shoreline convergence in the future without project scenario. The lateral movement of Timbalier Island causes accretion on the western portion of the island at the expense of the eastern end. Over the last 100 years, the Timbalier Islands have been reduced from 1,677 to 780 ha (4,144 to 1,927 acres) (Williams *et al.* 1992.)

2.3.3. Caminada-Moreau Headland / Grand Isle

The Caminada-Moreau Headland is unique to the Phase 1 Study Area in that it is an attached headland and does not contain a bay shoreline. The Headland has experienced some of the highest rates of shoreline erosion on the Louisiana coastline. Another difference from the barrier islands is that the Headland consists of cohesive deltaic sediments and a sandy ridge that have generally been transported laterally or offshore (Williams *et al.* 1992).

Meanwhile, Grand Isle has one of the smallest erosion rates along the Louisiana coastline and is unique in that it is the only populated island in the Phase 1 Study Area. Grand Isle also has jetties, breakwaters, and a dune and beach fill program that have contributed to recent shoreline change on and adjacent to the island. Since 1954, Grand Isle has received in excess of 2 million cubic yards of beach fill (Gravens and Rosati 1994).

The shoreline movement and magnitude of change within this sub-area contrasts greatly. The Caminada-Moreau Headland has had an average shoreline retreat of -13.3 m/yr (43.6 ft/yr) over the last 100 years. Over 100 years, Grand Isle has experienced an average shoreline *advance* of +0.9 m/yr (3.0 ft), while the bayside has eroded -1.0 m/yr (3.3 ft/yr). Grand Isle has decreased from 1,059 to 960 ha (2,617 to 2,372 acres) during the same time (Williams *et al.* 1992). Current changes in shoreline morphology at Grand Isle are most likely to be the result of human intervention either through beach fills and/or breakwaters and jetties.

2.3.4. Plaquemines Shoreline

The Plaquemines shoreline extends from the Grande Terre Islands to Sandy Point, encompassing 48 km (30 mi) of narrow islands. The Plaquemines shoreline consists of narrow, low-lying, and highly segmented islands. The Plaquemines sub-area has experienced severe coastal erosion due to lack of sediment, subsidence, storms, and human impacts (Williams *et al.* 1992).

From 1884 to 1988, the gulfside shoreline eroded -5.5 m/yr (18.0 ft/yr), while the bayside migrated landward at 0.4 m/yr (1.3 ft/yr). During this time, the average shoreline width changed from 487 to 263 m (1,598 to 863 ft). Williams *et al.* (1992) were only able to calculate the long-term area change for Grande Terre and Shell Island. From 1884 to 1988, Grande Terre decreased from 1,699 to 513 ha (4,198 to 1,268 acres), and Shell Island decreased from 122 to 69 ha (301 to 171 acres).

3.0 BORROW SITE CHARACTERISTICS

Information on potential borrow sources was compiled using existing reports, data from previous projects, and communication with the dredging industry. Existing information is very limited and should be interpreted within the constraints of preliminary findings of an in-house investigation. A detailed geotechnical investigation should be performed in the engineering design phase to provide actual volumes and composition of sediment. Pending the results of a geotechnical investigation, the recommended sand sources may vary from those recommended in this report.

Suter *et al.* (1991) completed an inventory of sand resources from Marsh Island to Sandy Point. Their analysis used previous data, seismic reflection, and vibracores to classify and quantify sediment sources. This is the primary report used to characterize potential sand sources for the Barrier Island Plan.

Byrnes and Groat (1991) analyzed using Ship Shoal sand for beach replenishment of the Isles Dernieres. This report provides a detailed description of the shoal's sediment composition and volume of material available at different stratums. In addition, the report provides preliminary estimates for the unit cost to remove sand from the shoal and place it at Isles Dernieres.

Previous projects also provide insight on material used to repair and restore Isles Dernieres. These projects used containment levees to rebuild dunes and marsh on the existing island. Actual cost estimates and overfill factors for such methods will be used in the preliminary design.

An *overfill* factor (ratio) is the volume of borrow material needed to produce a stable unit of beach fill. The overfill factor is based on a comparison of grain size characteristics between the native and borrow materials. Different sediment characteristics among the borrow sites produces varying overfill factors. If a borrow area has a high content of silts or clays, the overfill factor will almost always be larger than that for an area with a higher composition of sand. Overfill factors will be used to estimate the volume of borrow material needed for unconfined beach fill.

Similarly, a *cut to fill* factor is included for both unconfined and confined fill (dunes, marsh platform). The cut to fill factor accounts for losses in the dredging process, such as transportation, placement, and dewatering of the borrow material. Previous projects have produced a 1.5:1 cut to fill ratio. This factor will be multiplied by the quantity of <u>confined fill at the dune and marsh platform</u> to determine the total volume of material needed. For unconfined fill, the <u>cut to fill factor will be multiplied by the overfill factor and the volume of beach fill</u> to determine the net section borrow quantities needed.

T.L. James & Co., Inc. (TLJ) and C.F. Bean Dredging Corporation (CFB) provided cost sheets and estimates from previous projects. TLJ also provided general cost information for the proposed alternatives and discussed some of the difficulties and constraints associated with dredging under certain conditions. These will be used to compute the unit cost for dredging and placing material throughout the study area.

The criteria for choosing a preferred borrow source is based on a number of factors. First, material used to construct barrier island projects needs to be quality material (high sand composition) that can be transported to the project site cost effectively. If there are no major differences in the impacts of dredging between two borrow areas, the lowest unit price (unit cost times the overfill factor) will be used. Second, the displacement of sediment from a borrow location should not create major adverse impacts, such as major increases in wave height that would possibly increase erosion to unprotected shorelines or allow oil and gas facilities to become more susceptible to damages from waves. Lastly, potential borrow sites are limited to tidal channels and deltas, offshore shoals, and river sediments. These areas are the closest in proximity to the islands and have the best chance of having sand quality that is desirable for construction on the islands.

Back bay sediments, although used in previous barrier island projects, have not been considered as a major source of material for these alternatives. Removing material directly from behind the islands in such large amounts, as would be required, could potentially increase wave heights directly behind the island. Also, dredging large holes behind the islands will hinder the natural migration of barrier islands to the north because overwashed material will then be needed to fill borrow pits. Back bay sediments, although not considered in this analysis, may be viable sediment sources for smaller projects and, possibly, maintenance of alternatives.

3.1. Isles Dernieres

Potential borrow sources for the Isles Dernieres include: Ship Shoal, Coupe Colin ebb-tidal delta, Whiskey Pass ebb-tidal delta, and the Cat Island Pass ebb- and flood-tidal deltas. Certain tidal inlets are closed as part of each alternative. Therefore, the analysis includes only the ebb-tidal shoals in those inlets that remain open.

3.1.1. Ship Shoal

Ship Shoal is a borrow source that could be used for either alternative. Review of previous reports indicates that Ship Shoal, located 15 km (9.3 mi) south of the Isle Dernieres, is the most compatible sand source and contains 1.2 billion cubic yards of sediment (Byrnes and Groat 1991). Ship Shoal contains 99% sand in specific areas with an estimated overfill ratio of 1.03:1 (1.03 cubic yards needed to offset 1 cubic yard of native material) for the Isles Dernieres. Byrnes and Groat (1991) reported that a 16,000 cubic yard hopper dredge could place ten million cubic yards of sand on the Isles Dernieres for $3.10/ cubic yard or $5.19/ cubic yard for one million cubic yards.

Review of previous projects, along the East Coast and Florida gulf coast by TLJ and CFB, indicate that this project could cost between $5.00 and $6.00 per cubic yard. The dredging companies did not recommend a specific type of dredge, but indicated that a cutterhead, hopper, or scow barge operation could be used, depending on the actual size of the project, equipment availability, and the time of year of construction. For the analysis, a reasonable cost to dredge and deposit Ship Shoal sand on the Isles Dernieres is estimated at $4.50/ cubic yard, excluding mobilization/demobilization. An overfill ratio using Ship Shoal sand of 1.03:1 will be used for both confined and unconfined fill.

3.1.2. Tidal Deltas

According to Suter *et al.* (1991), the ebb-tidal shoals contain a larger percentage of sand than the flood-tidal deltas. For this analysis, dredging in tidal inlets is limited to areas that are not directly offshore from the islands being restored. Some ebb-tidal shoals are located directly offshore of the islands and these areas are not considered engineeringly practical. Also, all tidal shoals, or portions of shoals, discussed in the sub-areas exist within the boundaries of state water bottoms.

Tidal deltas in the Isles Dernieres sub-area must be analyzed independently for each alternative. In this sub-area, different passes are closed for each alternative. For example, Whiskey Pass is closed in Alternative 1, thus the Whiskey Pass ebb-tidal delta is not recommended as a borrow source. Meanwhile, Whiskey Pass remains open in Alternative 2 and could be used as a borrow source. Therefore, the use of tidal deltas as borrow areas has been separated for each Isles Dernieres alternative.

3.1.2.1. Alternative 1

The Coupe Colin ebb-tidal delta and Cat Island Pass ebb- and flood-tidal deltas are potential borrow sites. The Coupe Colin ebb-tidal delta has an average sand thickness of 2 m (6.6 ft), contains 90% sand, and has an estimated volume of 42 million cubic yards of material with no overburden (Suter *et al.* 1991). This sand has an overfill ratio of 1.13:1.

The Cat Island Pass ebb- and flood-tidal deltas range from 75-88% sand and have a total volume of 250 million cubic yards of material ranging from 1.5-4.0 m (4.9-13.1 ft) thick (Suter *et al.* 1991). There is little overburden on the shoals and overfill factors range from 1.05-2.03 in the nearshore.

TLJ indicates that material near the islands can be dredged using a cutterhead operation. This reduces the cost and maximizes the transport efficiency. The estimated unit cost to dredge these areas is assumed to be $1.30/cubic yard (net section borrow) due to the long pumping distance and is in-line with the unit price used at East Isle.

For this analysis, an overfill factor of 1.54 (average overfill factor between the borrow sites) will be used for unconfined fill, while confined fill will have a factor of 1.5. Hydraulic fill unit costs will be $1.30/ cubic yard.

3.1.2.2. Alternative 2

Alternative 2 for the Isles Dernieres involves closing the area behind Coupe Colin and letting Whiskey Pass remain open. Therefore, no dredging of the Coupe Colin tidal deltas will be considered for Alternative 2. Instead, the Whiskey Pass and the Cat Island Pass ebb- and flood-tidal deltas could be potential borrow areas. The Whiskey Pass tidal deltas have an average sand thickness of 4.9-6.6 m (16.1-21.7 ft) with sand composition ranging from 75-90%. The result is an overall volume of 25 million cubic yards available in Whiskey Pass (Suter *et al.* 1991).

For this analysis, an overfill ratio of 1.52:1 will be used for unconfined fill to account for overburden and losses, while confined fill will have a cut to fill factor of 1.5. Unit cost will be $1.30/ cubic yard.

3.1.3. Preferred Borrow Source

Based on available information, the tidal shoals are the preferred borrow source assuming enough material is available to construct the alternatives. Alternatives 1 and 2 are primarily confined fill placement for the dune and marsh platform. Confined fill is cheaper using material from tidal shoals than from Ship Shoal. Unconfined fill is $1.30/cubic yard using material from tidal shoals and $4.50/cubic yard using Ship Shoal material. Therefore, the tidal shoals are preferred economically over Ship Shoal sand. (Prior to final design, more detailed sampling of the inlets is recommended.).

However, it is suggested that Ship Shoal, shown in Figure 4, be the preferred borrow source for maintenance of the alternatives at the Isles Dernieres for a number of reasons. First, it may be difficult to construct the initial alternatives using the available sand in the inlets. The assumptions made in Suter *et al*. (1991) may overestimate the actual sand available, in which case another sand source (Ship Shoal) would have to be found. Next, the impacts due to initial construction dredging will remove most of the available sand from the system and place it on or near the islands. For maintenance of the projects, Ship Shoal will add compatible sand not only to the island, but to the overall system. Finally, a continued effort to remove sand from the inlets could result in adverse impacts by allowing gulf waves to propagate further inland and could increase salinity in the bays. Previous experience behind the island has shown that areas dredged tend to fill in through the natural movement of sediment from the islands and bays. It is recommended that previous borrow sites in the passes and near the island be allowed to fill back in naturally. Therefore, Ship Shoal should be the primary source of sand for maintaining the proposed alternatives. The recommended borrow locations are shown in Figures 4 and 5 for Alternatives 1 and 2, respectively.

3.2. Timbalier Islands

Borrow sources for the Timbalier Islands include: the Cat Island Pass and Little Pass ebb- and flood-tidal deltas (See Figures 4 and 5). These are potential borrow areas for both alternatives, as both tidal inlets remain open.

3.2.1. Cat Island Pass

As discussed in Section 3.1.2.1, Cat Island Pass has a combined sediment volume of 250 million cubic yards of sediment ranging from 75-88% sand. Sand deposits have a thickness of 1.5-4.0 m (4.9-13.1 ft) (Suter *et al.* 1991). This borrow site could serve as the source of sand for Timbalier Island, as well as the eastern portion of the Isles Dernieres. Sand has accumulated along the western end of Timbalier Island creating shallow offshore shoals.

3.2.2. Little Pass

Little Pass contains a large ebb- and flood-tidal delta with an estimated 194 million cubic yards of material ranging from 75-98% sand with layers 1.5-2.0 m (4.9-6.6 ft)thick. Little overburden material is found in these areas (Suter *et al.* 1991). Material from these tidal shoals can be used to restore Timbalier and/or East Timbalier Islands. Alternatives 1 and 2 close Raccoon Pass and restore East Timbalier Island, thus the Raccoon Pass tidal shoals are not recommended as borrow sources.

An overfill factor was unobtainable for unconfined fill using the flood-tidal delta. The average grain size determined by Suter *et al.*(1991) is small and is better suited for confined fill if needed. The ebb-tidal delta has an unconfined overfill factor of 1.21. Confined fill will use a 1.5 cut to fill factor.

Unit prices for dredge fill are estimated at $1.30/cubic yard. The recommended borrow locations for the Timbalier Islands are shown in Figures 4 and 5.

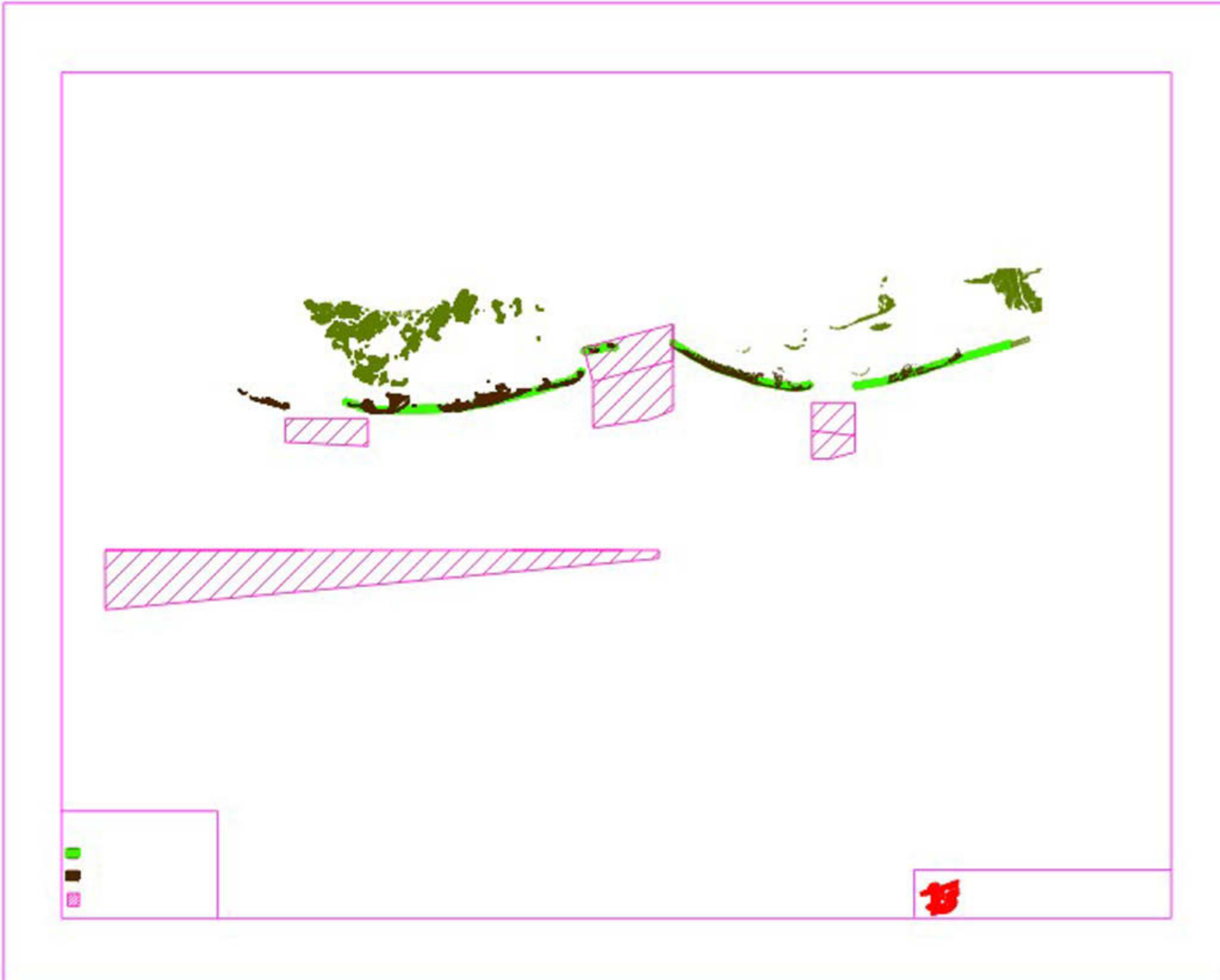


Figure 4. Isles Dernieres and Timbalier Islands Borrow Areas - Alternative 1

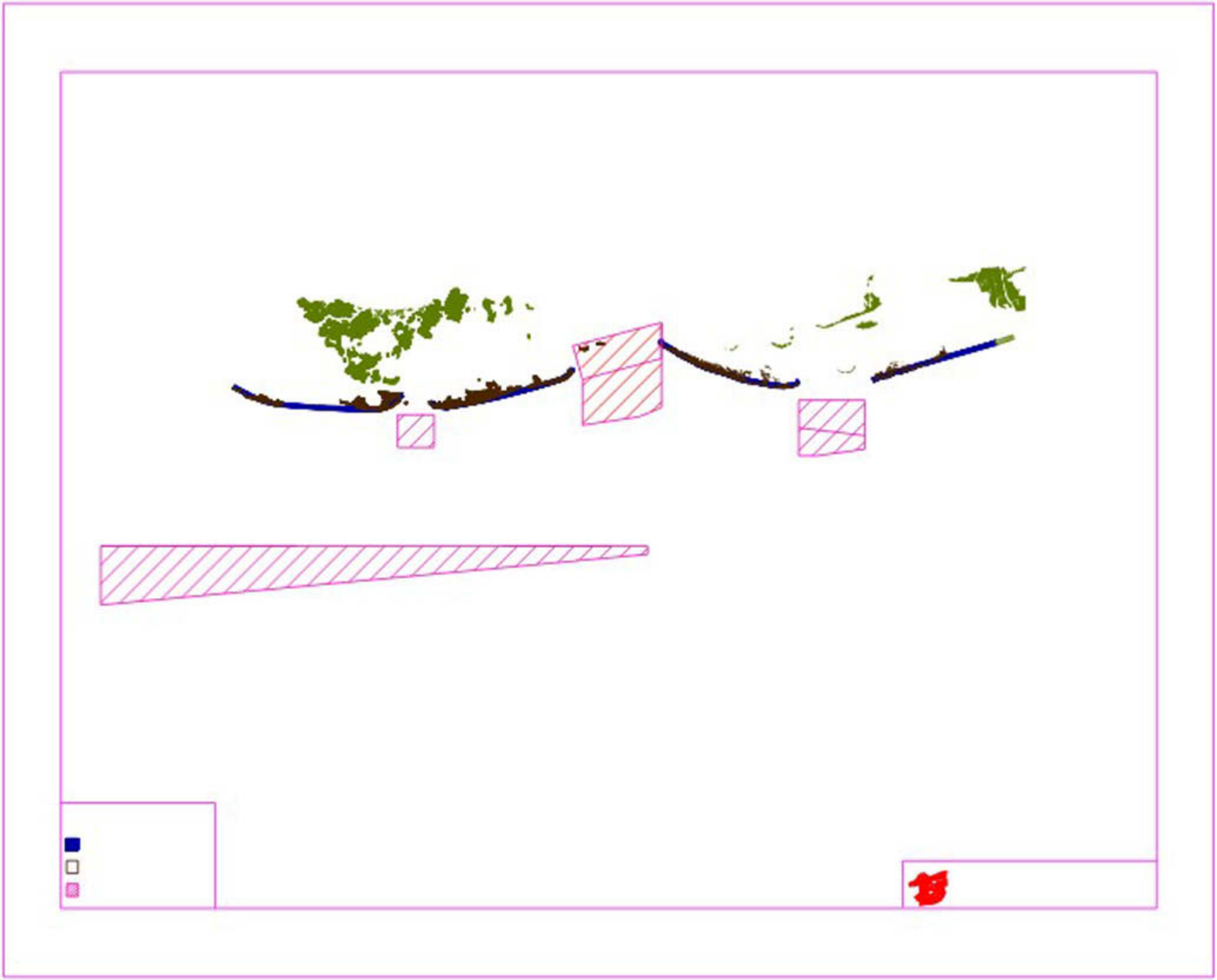


Figure 5. Isles Dernieres and Timbalier Islands Borrow Areas - Alternative 1

3.3. Caminada-Moreau Headland

The borrow source for the Caminada-Moreau Headland is the Caminada-Pass ebb-tidal delta. Approximately 24 million cubic yards of sediment are available with a sand thickness of 2 m (6.6 ft). The sand body is composed of 99% sand (Suter *et al.* 1991). For this analysis, it is assumed that a hydraulic dredge will pump the material directly to the site for $1.80/ cubic yard. The increase cost is due to the long pumping distance to the western extent of the headland (53,000 feet), where most of the material is needed. This assumes an approximate increase of 40 percent due to the need to use booster pumps. A contractor may also be inclined to use a hopper dredge for this work. For this analysis, the $1.80/cubic yard estimate is presumably on the low end of potential unit prices.

The unconfined overfill factor using this material is 3.53. The overfill factor is based on the median grain size and standard deviation reported in Suter *et al.* (1991) for the Caminada Pass ebb-tidal delta compared to the average grain size reported for the shoreline using Ritchie *et al.* (1995). A cut to fill factor of 1.5 will be used for confined fill. The recommended borrow locations for the Caminada-Moreau Headland are shown in Figure 6.

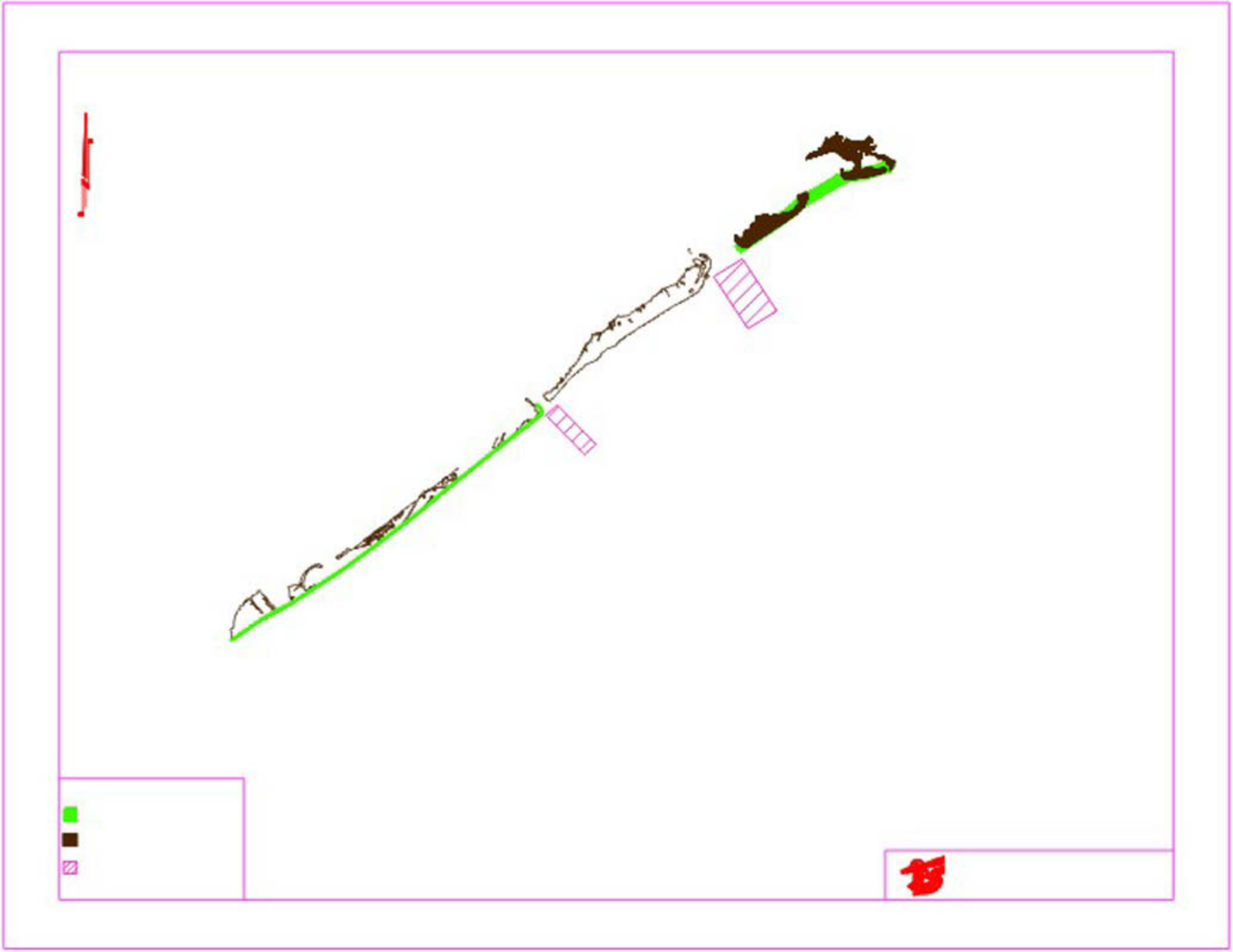


Figure 6. Caminada-Moreau Headland Borrow Areas - Alternative 1

3.4. Plaquemines Shoreline

Potential borrow locations for the Plaquemines shoreline consist of ebb-tidal deltas, distributary channels, and river sediments. The Plaquemines area is limited in the availability of sand, based on Suter *et al.* (1991). Many tidal inlets have inferior material or require dredging in unsuitable locations.

TLJ estimated that dredging in the proposed ebb-tidal deltas and distributary channels areas would cost between $1.00 and $1.20 per cubic yard. For this analysis, a more conservative the unit price is assumed to be $1.30/cubic yard.

The use of river sediments was analyzed using information contained in *Feasibility of Using Dredge Material Using Pipelines and Dredged Sediments to Restore Wetlands in Terrebonne Parish* (Woodward-Clyde Consultants (WCC) 1991).

3.4.1. Ebb-Tidal Deltas

The western ebb-tidal deltas include Barataria Pass, Pass Abel, Quatre Bayou, and Grand Bayou Pass. Dredging the shoal at Pass Abel is not suggested for Alternative 1, as the inlet is to be closed.

The Barataria Pass ebb-tidal delta contains 71 million cubic yards of sediment with a sand thickness of 2 m (6.6 ft). Here sand composition is 94% with little or no overburden. The unconfined overfill factor is 1.76, while the confined cut to fill factor is 1.5. Suter *et al.* (1991) recommended this site as a possible borrow source due to the composition and volume of sand, as well as the natural longshore replenishment tendencies to sustain the delta.

The Pass Abel ebb-tidal delta is similar to the Barataria Pass ebb-tidal delta, with a reduced overfill factor of 1.41 for unconfined fill. The shoal contains 14 million cubic yards of sediment with an average sand thickness of 2 m (6.6 ft) (Suter *et al.* 1991). A 95% sand composition is estimated for this site. This site is only recommended for Alternative 2.

The Quatre Bayou Pass ebb-tidal delta has an estimated 26 million cubic yards of sediment with an average sand thickness of 2 m (6.6 ft). Sand composition varies from 10-90% and contains little or no overburden (Howard 1982). An overfill factor of 1.41 is estimated for unconfined fill, while the confined fill factor is 1.5. This site was previously targeted as a primary borrow site for potential restoration of Cheniere Ronquille (Moslow 1986).

The Grand Bayou Pass ebb-tidal delta is located along the central portion of the Plaquemines shoreline. The shoal contains approximately 8 million cubic yards of sediment with a sand thickness of 1.5 m (4.9 ft). Sand composition is >75% and has little or no overburden (Suter *et al.* 1991). An unconfined overfill factor of 4.99 is estimated with an estimated confined cut to fill factor of 1.5.

3.4.2. Distributary Channels

Distributary channels along the eastern Plaquemines shoreline are the primary available source of material in this region. Specifically, the Eastern Scofield and Dry Cypress distributary channels were analyzed for these areas. Dredging in these areas is estimated at $1.30/ cubic yard.

The Eastern Scofield distributary channel contains 109 million cubic yards of sediment. Sand composition is estimated at 90% with an average thickness of 9 m (29.5 ft). However, the sediment has an overburden thickness of 3-4 m (9.8-13.1 ft) composed of silty clays (Suter *et al.* 1991). Therefore, dredging for sand in this area involves removing the top 3-4 m (9.8-13.1 ft) of clay before sand is found. The estimated unconfined overfill factor is 1.41. Assuming a dredging depth of 8 m (26.2 ft) below the mudline, the overfill factor is doubled to 2.82 for unconfined fill and 1.5 for confined fill.

The Dry Cypress Bayou distributary channel is similar to Eastern Scofield and contains 171 million cubic yards of material. Much of the estimated volume of material in both Eastern Scofield and the Dry Cypress Bayou channels lie in Federal waters beyond the water depth limit for dredging economically.

The sand thickness is 9 m (29.5 ft) with 90% sand composition (Suter *et al.* 1991). A 2.5 m (8.2 ft) overburden must be removed to obtain sand. An unconfined overfill factor of 1.0 is estimated for this site, but is adjusted to 2.0 to account for overburden. Confined fill has a cut to fill factor of 1.5. A thorough engineering sediment sampling investigation of these distributary channels is recommended to verify actual sediment composition at these depths.

3.4.3. River Sediments

The Plaquemines shoreline is the closest sub-area to the Mississippi River. The Mississippi River contains fine sand that is only limited by the rate at which it can be dredged (WCC 1991). For this analysis, it is assumed that a 1:1 overfill ratio exists between native and river sand. The dredging scenario is to dredge the river between Nairn and Empire using a hydraulic dredge. A scow barge or hopper dredge operation is unfeasible due to the need to travel to the mouth of the river and then travel north for disposal. The hydraulic dredge would pump sand over the river levee, across Bayou Adams and Bastian Bay, and then deposit it in Grand Bayou Pass for further rehandling or natural distribution. The pumping distance is approximately 9-12 miles.

The cost to pump material this distance is estimated at $6.00/cubic yard according to estimates by WCC (1991). This assumes a pumping capacity of 10,000 cubic yard/day, which is low for a 30-inch dredge. If the capacity doubled, the unit price c could decrease to $3.00/cubic yard.

The recommended borrow sites for the Plaquemines shoreline are the distributary channels and tidal deltas shown in Figures 7 and 8. The distributary channels and tidal deltas offer the last expensive material when factoring in unit costs and overfill factors. However, future sediment diversions and beneficial use of maintenance dredge material by the Corps of Engineers are viable options in the Plaquemines sub-area. The Plaquemines shoreline will require large maintenance costs if beach options are feasible. If so, the unlimited supply of sand in the Mississippi River should be pursued as a long-term sand resource. Using maintenance dredge material from the Mississippi River may offer some significant cost savings. Combining the funds available for navigational dredging with potential funding for dedicated dredging for coastal restoration of the Plaquemines shoreline may increase the likelihood for using the Mississippi River as the preferred borrow source.

3.5. Considerations

Available information was used to quantify borrow site volumes and probable overfill factors. A thorough hydrographic survey and core sampling program must precede more refined engineering design. In addition, pipelines, wells, and other structures, not identified at this level of analysis, may pose some potential problems for dredging in some of the proposed sites. Use of Ship Shoal sand requires a lease from the Minerals Management Service, which requires an Environmental Impact Statement on the proposed use of the sand at Isles Dernieres. If a maintenance program is to be implemented, a lease from the Minerals Management Service should be completed prior to the first beach nourishment project.

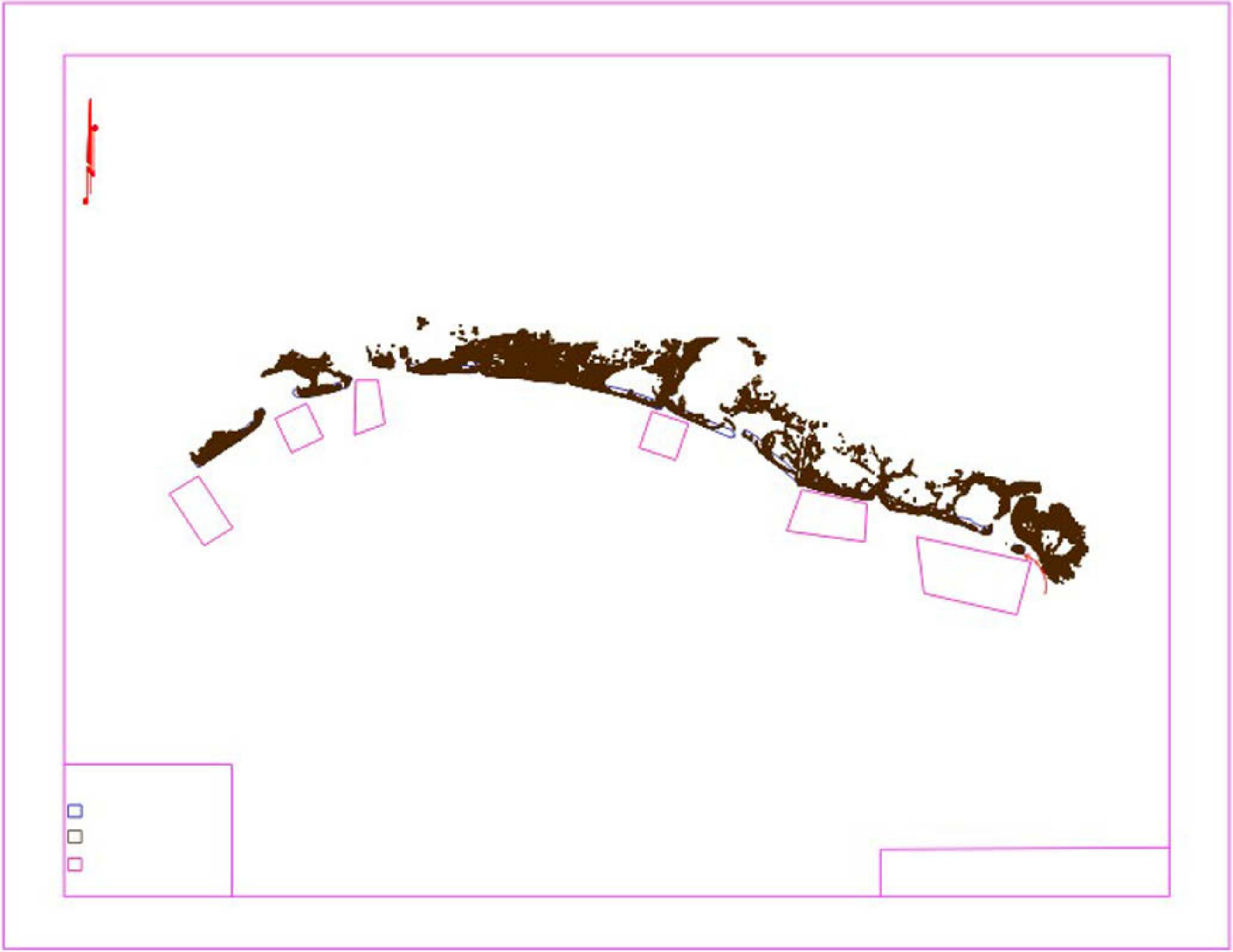


Figure 7. Plaquemines Shoreline Borrow Areas - Alternative 1

Figure 8. Plaquemines Shoreline Borrow Areas - Alternative 2

4.0 DESCRIPTION OF METHODS AND ALTERNATIVES

4.1. Project Purpose

The purpose of the project is to determine the optimal barrier shoreline configuration of the Phase 1 Study Area to maximize coastal resource benefits. Benefits range from creation and protection of habitat to reducing storm surge and protecting infrastructure. In Step J of the Barrier Shoreline Feasibility Study, the benefits of the management alternatives are predicted using numerical models, existing data, and professional judgment. The alternatives were developed without a maximum cost limit, but with a recognition that ultimately the benefits would have to justify the costs.

The goals the team had in developing the preliminary design were to:

1. Reduce storm surge elevations in populated areas
2. Reduce wave energy in the bays
3. Create wetland habitat on the islands
4. Reduce wetland loss
5. Enhance recreational capacity of the islands and bays
6. Optimize sediment management in the system
7. Minimize maintenance costs

Except for Grand Isle, there are no permanent residents on any of the barrier islands. Camps, docks, and mineral production facilities are the primary infrastructure located on the islands. In the event of a large storm or hurricane, the facilities would likely be evacuated. Therefore, the effects of flooding on the island pertain to damaging facilities rather than loss of life. The facilities on or near the islands are elevated to contend with flooding due to storms. This does not imply that the structures were designed to withstand the effects of a hurricane without the sheltering effects of the islands. Merely, the sole effects of rising water do not necessarily translate into destruction of those facilities.

Also, the recreational value occurring directly on the barrier islands is primarily day-boating trips, fishing camps, recreational fishing on or near the shore, and recreational beaches, particularly at Grand Isle. Unlike other beach fill projects, this project is not constrained by recreation and tourism. The projects are not intended to create subaerial recreational beaches and storm surge benefits to businesses and homes near the ocean. These barrier islands are dynamic and benefit coastal parishes landward from their locations as well as providing sustainable habitat for many aquatic and terrestrial species.

4.2. Previous Project Designs

4.2.1. Background

To date, only a few island restoration projects have been implemented in the Phase 1 Study Area. Grand Isle has an established dune and beach nourishment program. Placement of sand on Raccoon Island, Wine Island, East Isle, Timbalier Island, East Timbalier Island, and Grande Terre has been limited to confined disposal in the berm and back side of the islands. Despite the low frequency of beach fills and island maintenance, information and experience gained from these projects can be used to achieve an island configuration that meets design goals and is cost effective.

According to the Corps of Engineer's *National Shoreline Study* (USACE 1971), the gulf shoreline at Grand Isle is the only critical eroding shoreline in the Phase 1 Study Area. In this report, "critical eroding shorelines" is defined as:

> "...areas experiencing significant erosion were categorized as critical if the rate of erosion, considered in conjunction with economic, industrial, recreational, agricultural, navigational, population trend, ecological, and other relevant factors, indicated that action to halt erosion may be or become justifiable. This is perhaps the reason little Federal money has been spent to protect gulf and bay shorelines in the past. Table 5 shows the breakdown of the study's results."

Under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA), approximately $30 million has been allocated for barrier island restoration. These projects are a significant step towards restoring and sustaining the Louisiana barrier shoreline. The Barrier Shoreline Feasibility Study was then enacted by CWPPRA to develop a comprehensive statewide plan for the optimal configuration of barrier islands to protect and enhance coastal resources.

Table 5. Louisiana Shoreline Classifications (Miles) (from USACE 1971)

	Terrebonne/Timbalier Bays*	Caminada/Barataria Bays*	Bastion Bay*	Phase 1 Gulf Shoreline	Louisiana**
Physical Characteristics					
Shore with beach zone (sand)	111.0	40.0	23.0	100.0	835.0
Shore without beach zone (mud and/or silt)	102.0	134.0	6.0	0.0	1108.0
Historical Shore Changes					
Critical Shore Erosion	0.0	0.0	0.0	6.4	29.3
Non-critical shore erosion	213.0	174.0	29.0	92.6	1553.8
Non-eroding shore (stable or accreting)	0.0	0.0	0.0	1.0	359.9
Shore Ownership					
Public, Federal	0.0	0.2	0.0	0.0	245.5
Public, non-Federal	18.5	17.2	4.8	25.8	331.9
Private	194.5	156.6	24.2	74.2	1365.6
Shore Use					
Recreation, public	0.0	0.1	0.0	7.3	17.8
Recreation, private	0.0	7.4	0.0	0.0	28.2
Non-recreation development	0.0	4.3	0.0	1.3	46.3
Undeveloped	213.0	162.2	29.0	91.4	1850.7
Total	213.0	174.0	29.0	100.0	1943.0

* Includes Bay, Lake, and Estuary Shorelines
** Includes Gulf, Bay, Lake, and Estuary Shorelines

4.2.2. Previous Design Criteria

Isle Dernieres

The design criteria for the emergency restoration projects at Raccoon Island and East Isle were governed by the funds available. The two projects were allotted repair and restoration money through the Federal Emergency Management Act (FEMA) to close breaches and raise island elevation to prevent overwash. Design goals were focused towards repairing critical areas under the available budget constraints.

Though the CWPPRA projects at Trinity and East Isle have not been constructed at this time, a detailed design for the projects was completed in 1994 and again in 1997. The primary objective in the design was to build a dune system with a project life of 20 years. This translates to a dune crest elevation of +8.0 ft referenced to the National Geodetic Vertical Datum (NGVD), which was the estimated surge height for a storm with a 5% chance of occurring (Traverse 1988). The dune crest width is 300 ft. The dune and beach berm were merged in a sloping front dune ranging from 1:50 to 1:22.5. The back dune was designed with a slope of 1:10. The original project width of the combined dune systems combined was 26,100 ft, but was expanded to 40,000 ft.

Whiskey Island, also funded through CWPPRA, has yet to be constructed. The goal of this project is to create marsh along the backside of the island and close newly formed breaches. Design objectives for this project are similar to Trinity and East Isle, except that a large elevated dune was not considered.

In 1985, Terrebonne Parish constructed a project at East Isle. The project still exists and was surveyed in 1988, after surviving three hurricanes. The beach width was 1,000 ft wide at its base and 600 ft wide at its crest. The crest height averaged +5 ft (msl). It should be noted that no maintenance of the project was done after vegetation was planted on the fill site.

The Corps of Engineers was responsible for adding sediment to Wine Island in 1994 by using dredge material from Cat Island Pass. The island was surrounded by a stone revetment and material was placed on the island. Design criteria was limited to confining the material that was being placed on the island.

Timbalier Islands

Timbalier Island was repaired and restored along with East Isle in the FEMA projects completed in 1996. Dune repair, back dune construction, sand fencing, and vegetative plantings were included in the projects. Similar to East Isle, the coverage within the monetary limits of the project was the governing factor. The design elevation was +5.0 ft (NGVD) at the dune crest.

East Timbalier Island was the site of a mitigation project by Greenhill Petroleum, Inc. Here, 24 acres of wetlands were restored to the island due to a blowout at the facility located there. Design was limited to acreage created under the mitigation requirement.

East Timbalier has also been authorized for two CWPPRA projects to fill shallow ponds and close breaches in the island. Combinations of sand and rock will be used to restore and stabilize areas that are currently tidal influenced. Project size is limited to the funds authorized by CWPPRA.

Grand Isle

The design heights of the dunes at Grand Isle in 1994, ranged from +11.5 to +13.5 ft (NGVD). For a populated island such as Grand Isle, where property, businesses, and lives are at risk, an adequate dune and berm system was constructed and is maintained by the Corps of Engineers. The authorized project plan is designed to provide wave damage protection from surge and waves caused by a hurricane with an average frequency of recurrence of once every 50 years (USACE 1979). The 50-year event is associated with an +8.5 ft (msl) storm surge and a deepwater wave height and period of 8.2 ft and 7.3 seconds, respectively. Wave runup on the island is estimated at 2.2 ft. (USACE 1979).

The Grand Isle dune and beach fill plan has a vegetated dune elevated to +11.5 ft (msl) with a 10 ft. wide crown. Side slopes are 1:5, with a beach berm at an approximate width of 180 ft. wide. The berm slopes from +8.5 ft. (msl) at the toe of the dune down to +3.0 ft. (msl) at the berm boundary with a natural slope thereafter (USACE 1979). The approximate berm slope is 1:33, but does not mimic the natural slope of the island.

Grande Terre

Grande Terre was used as a beneficial disposal site for dredge material from the Barataria Waterway in 1996. The Corps of Engineers built retention dikes along the perimeter of the island and filled the containment area using the dredge spoil. No vegetative plantings or shaping of the retention dikes were included in the project. The primary focus of this project was to contain and dewater the necessary quantities of disposal material while adding needed elevation to the island to help offset erosion by decreasing the frequency of overwash.

4.2.3. Existing Structures

Leveeing of the Mississippi River has had the largest impact on the Deltaic Plain (van Beek and Meyer-Arendt 1982). In addition, coastal structures have been built along the shoreline of Louisiana to protect against wave erosion or to maintain passage through navigation channels. Coastal structures are built to counter or reduce the negative effects of certain coastal processes. Often times, areas downdrfit of these structures experience negative impacts and may erode at accelerated rates because of sediment deficiency.

Breakwaters are barriers placed parallel to the shoreline to provide an area of reduced wave energy and shelter along the beach. These barriers are typically constructed of stone. The reduction in wave energy facilitates deposition of sediment behind the barrier, resulting in creation or expansion of a beach. Groins or groin systems are barrier-type structures that extend from the backshore into the littoral zone. These structures modify the longshore movement of sand and promote accumulation of sand on the shore or retard sand losses. Jetties are used at inlets of the navigational channels. These structures reduce wave forces and regulate sand movement along adjacent beaches. Bulkheads are soil-retaining structures. These structures also dampen wave energies. Bulkheads can be constructed of steel, concrete, timber or other such materials. Revetments are stones (or other materials) placed to stabilize an existing sloped shoreline.

Coastal structures at the Isles Dernieres are limited to the smallest areas of the chain at Wine Island and Raccoon Island. In 1994, the Corps used material from the Houma Navigation Channel to rebuild part of Wine Island. Rocks were placed around the perimeter of the island to retain the material.

It should be noted that Adams *et al.* (1978) recommended that all structural measures at the Isles Dernieres should be prohibited due to the dynamic nature and migration tendencies of the islands. In 1997, seven breakwaters were constructed on the eastern end of Raccoon Island as a CWPPRA demonstration project. No beach fill was included with the project. A monitoring program should quantitatively show the effects of the breakwaters.

A rock seawall was built on the western gulf side of Timbalier Island in 1972. The portion of the island protected by the rocks extends out into the gulf beyond those areas adjacent to the structures. Unlike the rest of the island, there is no beach seaward of the rocks. The rocks are a barrier for natural beach migration, both accretional and erosive. Waves scour the beach seaward of the rocks causing deeper water at the toe of the structures. This allows waves to break directly on the seawall.

An onshore breakwater was built on East Timbalier Island in 1974 (van Beek and Debusschere 1994). The breakwaters are located on the beach and in the back-bay area. They are made of rip-rap and were placed to protect the oil and gas infrastructure located on the island. The project can be considered successful because they are protecting the oil infrastructure and remnants of the island do still exist. However, the breakwaters are frequently breached during storms, little sand exists seaward of the outer breakwater, and the western end has detached and acts as a shoal for Timbalier Island (van Beek and Meyer-Arendt 1982).

Jetties were constructed at Belle Passe to maintain navigation. The jetties were extended in the 1960's. Sediment travels westward at Port Fourchon, therefore the east jetty has experienced reduced erosion rates on the updrift side, while the western shoreline downdrift of the jetty has experienced increased erosion rates (van Beek and Meyer-Arendt 1982). The jetties cut off the Timbalier Islands from their primary sediment source. At Port Fourchon, offshore breakwaters were constructed using twelve sunken river barges. The barges were sunk approximately 500 ft. offshore in 1994. Since then, some of the barges have been severely damaged but remain a wave barrier to the shoreline.

In 1951, 14 timber groins were constructed at Grand Isle by the Louisiana Department of Highways in an attempt to curtail the sediment traveling eastward (Myers and Theis 1956). The groins built at Grand Isle had limited value in stabilizing the beach and were later removed (Adams *et al.* 1978). In 1957, a jetty was constructed near the eastern end of the island. The jetty trapped 764,000 m^3 (1,000,000 yd^3) of sediment within a four year period (USACE 1972). The jetty has stabilized Grand Isle, but increased the erosion on Grand Terre (Adams *et al.* 1978). On the western portion of Grand Isle, a jetty and revetment system was constructed in 1972 to prevent erosion on the western end of the island. The result was a stabilized western spit and a deprivation of natural beach nourishment downdrift of the area (van Beek and Meyer-Arendt 1982). A segmented offshore breakwater system was then constructed in 1994 along the eastern section of the island.

The Empire Jetties were constructed in the early 1950's. Prior to their construction, the short-term shoreline retreat rate was 4.5 to 6 m/yr (15 to 20 ft/yr). The jetties have since increased the erosion rate to 10.5 m/yr (35 ft/yr) immediately on the western downdrift side (van Beek and Meyer-Arendt 1982). In addition, the eastern updrift area has slightly eroded. This indicates either a small amount of westerly transport or an overall lack of sediment in the system where accretion cannot be found on either side of the jetties.

Structural measures may be an alternative in critical areas of erosion and where downdrift effects can be negated. Coastal structures used in the study area have had different effects. The rock seawall in front of Timbalier Island has stabilized the island in that area. Downdrift (west of the rocks) there is an abrupt erosive shoreline. At East Timbalier Island, a rock seawall was built in the late 1950's and the island continued to erode and break apart, stopping the landward migration of the island (Williams *et al.* 1992). The rocks now function as detached breakwaters. East Timbalier Island has experienced extreme erosion due to the Belle Passe jetties and the inability of sediment to move onto the island. However, erosion and overwash is noticeably less in areas where the breakwater is still functional.

Hard structures provide habitat for attached benthic organisms, demersal fishes, and macroinvertebrates. This type of habitat, no matter the structure, is rare to Louisiana.

4.3. Description of Alternatives

Two conceptual alternatives developed from the Step I - Formulation and Assessment of Strategic Options analysis. The alternatives were compared to other strategic options, such as a fall-back line, no-action scenario, historical configuration, and preservation of existing conditions. The resulting alternatives take the beneficial functions of these options and result in hybrid plans across the Phase 1 Study Area.

Alternative 1, as defined in Step I (Table 6), widens the barrier islands to 1,970 ft (600 m) and rebuilds the dunes to a +9.0 ft (+2.7 m) (msl) elevation. Mature inlets predating 1890 remain, while smaller inlets and breaches that formed subsequently are closed. Interior "wave absorbers" are built in the interior bays. They serve to shelter saline marsh shorelines from locally-generated waves and offshore waves propagating through the remaining inlets.

Alternative 2, as defined in Step I (Table 6), widens the islands to 1,230 ft (375 m) and builds the dune to a +6.5 ft (+2.0 m) (msl) elevation. Inlets present in 1988 remain open, except for Raccoon Pass. All other breaches are closed.

Table 6. Description of Alternatives from Step I Analysis

	Alternative 1	Alternative 2
Island width	±600 m (±1,970 ft)	±375 m (±1,230 ft)
Dune crest elevation	+2.7 m (+9.0 ft)	+2.0 m (+6.6 ft)
Marsh Platform	±490 m (±1,610 ft)	±260 m (±850 ft)
Wave Absorbers in Bays	yes	no

The Step I report contains a description of the needs of the system and the physical constraints behind the barrier island alternatives. First, the barrier islands should serve as habitat for the biological species that inhabit or utilize the shoreline in some aspect of their life-cycle. The islands would be constructed of sand, and the dune and the marsh platform are to be vegetated. The marsh platform slopes from a +5.0 ft down to a +2.0 ft and will become inter-tidal as rainfall run-off and waves reshape the island's bay shoreline. Second, the alternatives are to be built by expanding the existing island and closing newly formed inlets and breaches. Lastly, Alternative 1 includes wave absorbers that will be constructed to shelter northern bay shorelines from localized wave energy. A wave absorber is essentially an offshore segmented breakwater, although a variation of the wave absorber design may vary depending on actual site conditions. The wave absorbers will be placed parallel to the existing marsh shorelines. The conceptual cross sections of Alternatives 1 and 2 are shown in Figures 9 and 10. Plan views of each alternative are shown for each sub-area in Figures 11-17.

All topographic and hydrographic survey data used to calculate volumes were taken from existing sources, such as: *Louisiana Barrier Island Erosion Study Atlas of Shoreline Changes in Louisiana From 1853 to 1989, Louisiana Barrier Island Erosion Study Atlas of Sea-floor Changes From 1878 to 1989,* and *The Coastal Sand Dunes of Louisiana* (Williams *et al.* 1992; Ritchie *et al.* 1989; 1990; 1995; List *et al.* 1994). These sources of information are useful in that they provide a quantitative measurement of the dynamic changes of the Louisiana Barrier Shoreline using a long-term dataset. Long-term datasets account for daily changes due to wind, tides, and waves; as well as dramatic events such as hurricanes.

In order to determine the volume of material needed for the two alternatives, two methods of calculation were incorporated. In the Isles Dernieres, Timbalier, and Plaquemines sub-areas, a surface modeling system, called Quicksurf™, was incorporated. Quicksurf™ is a general purpose surface model that allows input of irregular mapping data and converts these into triangulated grids, eventually creating a 3-D surface. By using this tool, net section fill quantities were calculated between the two alternatives and the pre-project conditions.

In the Caminada-Moreau/Grand Isle sub-area, calculation of the volumes were computed manually. The headland area quantities were determined using the proposed backdune base as the baseline for each profile. The end-area volume method was used to compute these volumes. This method was chosen over Quicksurf™ due to the attachment of the shoreline to the headland and the need to only calculate beach and dune quantities from the profiles available in Ritchie (*et al.* 1995) and in the design alternatives.

The 1988 barrier islands were used as the pre-project conditions. Shoreline positions, bathymetry, and island elevations from 1988 were the most recent and concise available. The 1988 shoreline positions are a product of *Louisiana Barrier Island Erosion Study Atlas of Shoreline Changes in Louisiana* (Williams *et al.* 1992) and were supplied to T. Baker Smith & Son, Inc. by Randy McBride at the Louisiana State University - Coastal Studies Institute.

Elevation data for the islands are limited and cover a small portion of the overall island profile. The team used existing data from the Louisiana Geological Survey *Sand Dunes of Louisiana* (Ritchie *et al.* 1989; 1990; 1995). Also, survey data provided by T. Baker Smith & Son, Inc. was incorporated from island surveys in the Phase 1 Study Area. Both sources were used where applicable and elevations were interpolated along the beach and dune systems.

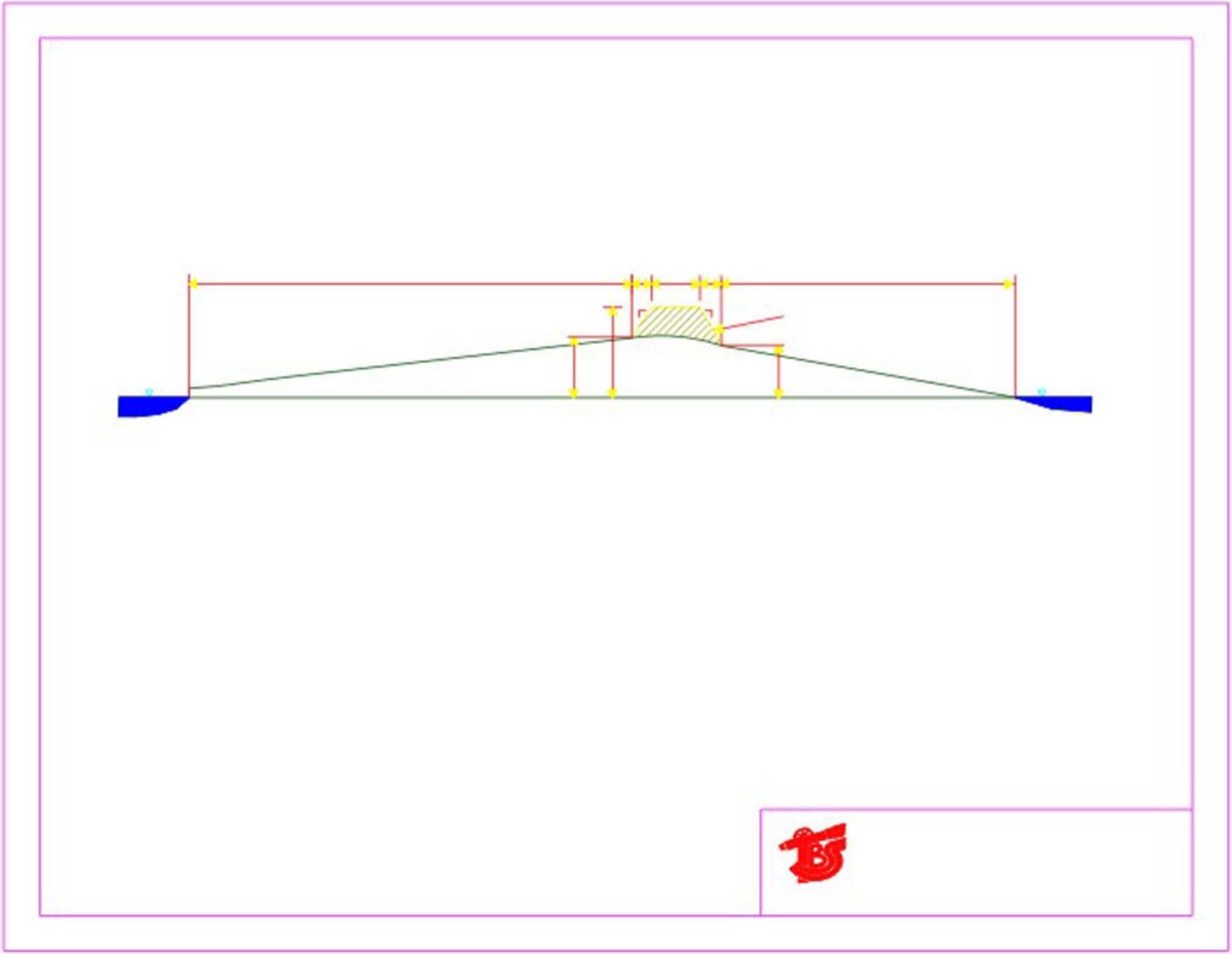


Figure 9.Typical Section - Alternative 1

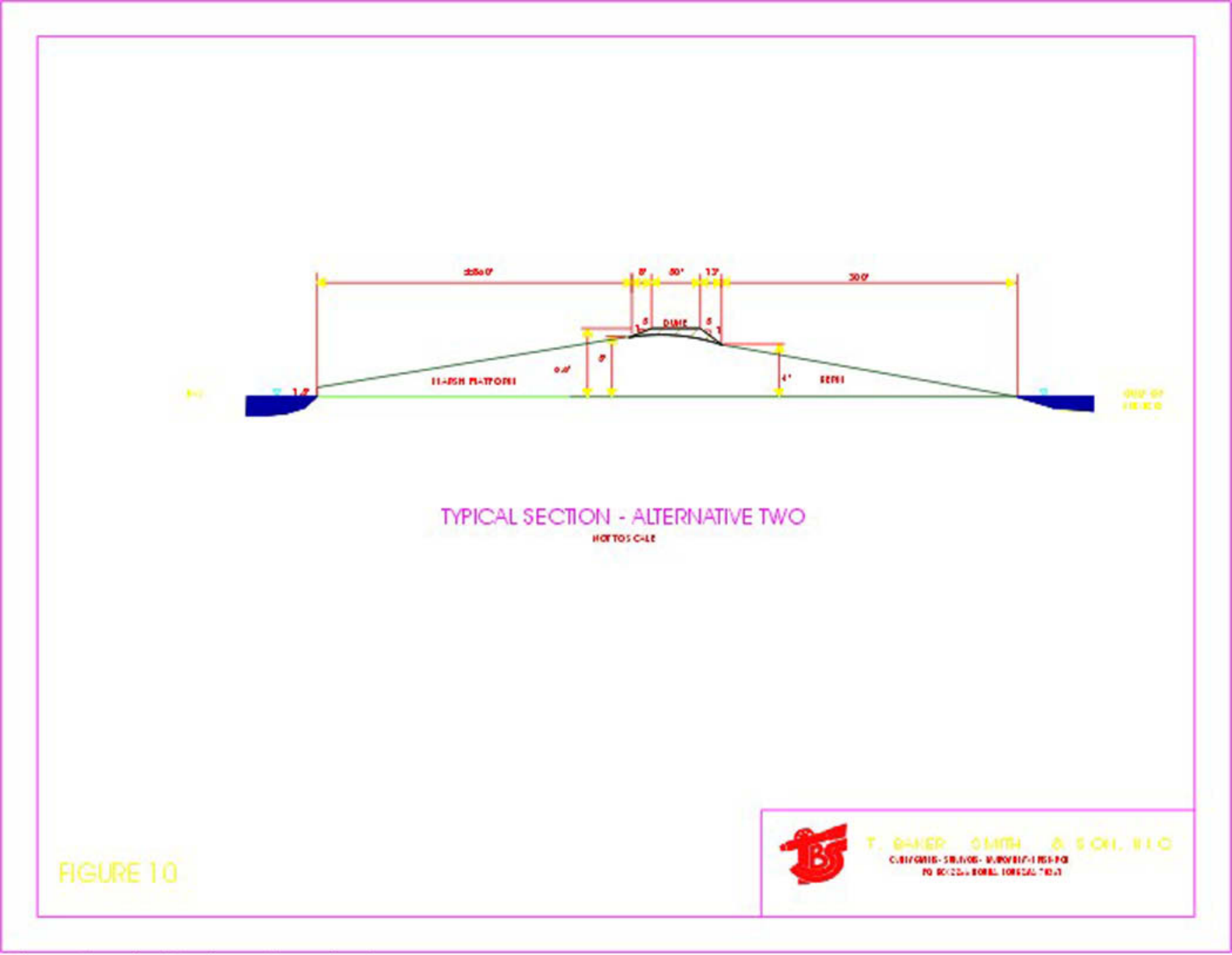


Figure 10.Typical Section - Alternative 2

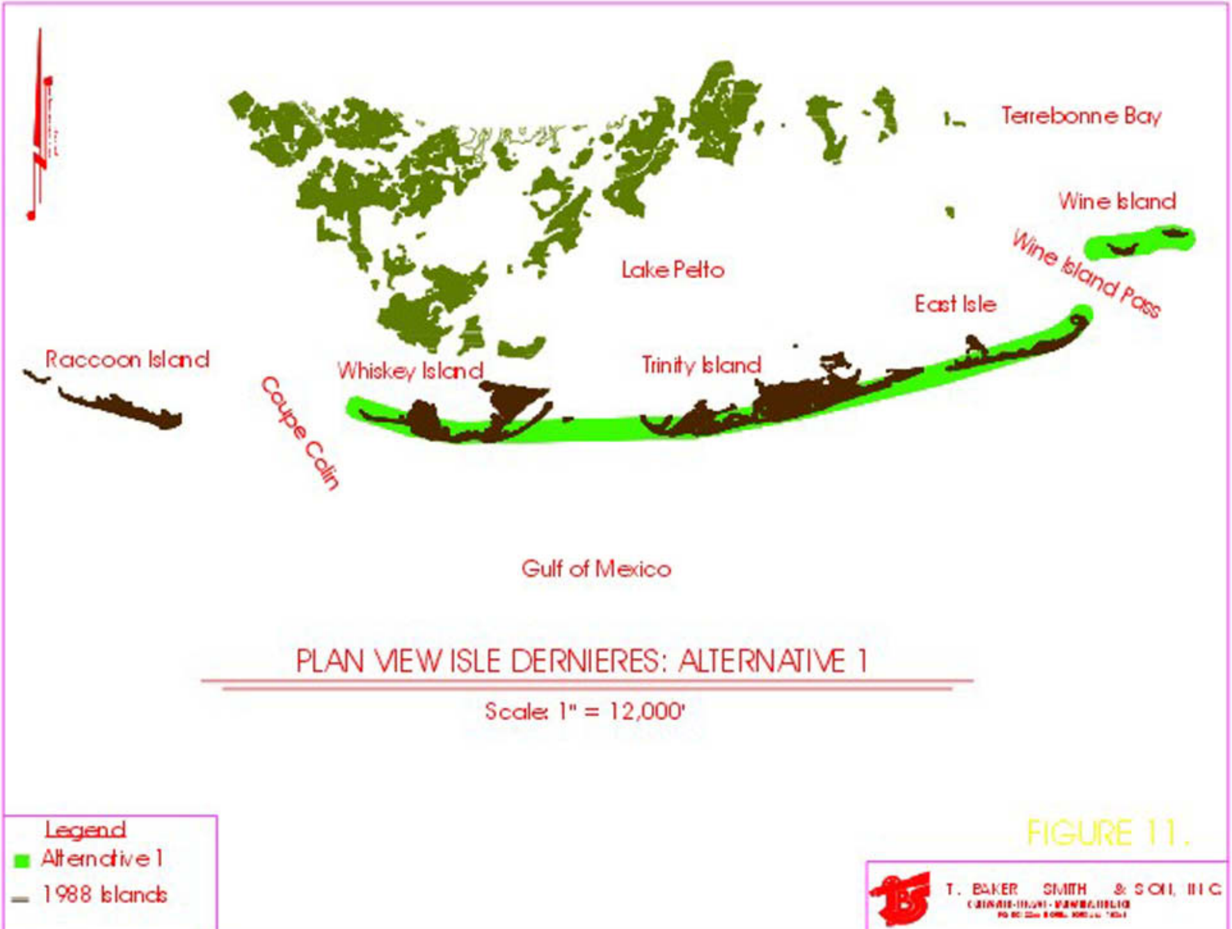


Figure 11. Plan View Isles Dernieres: Alternative 1

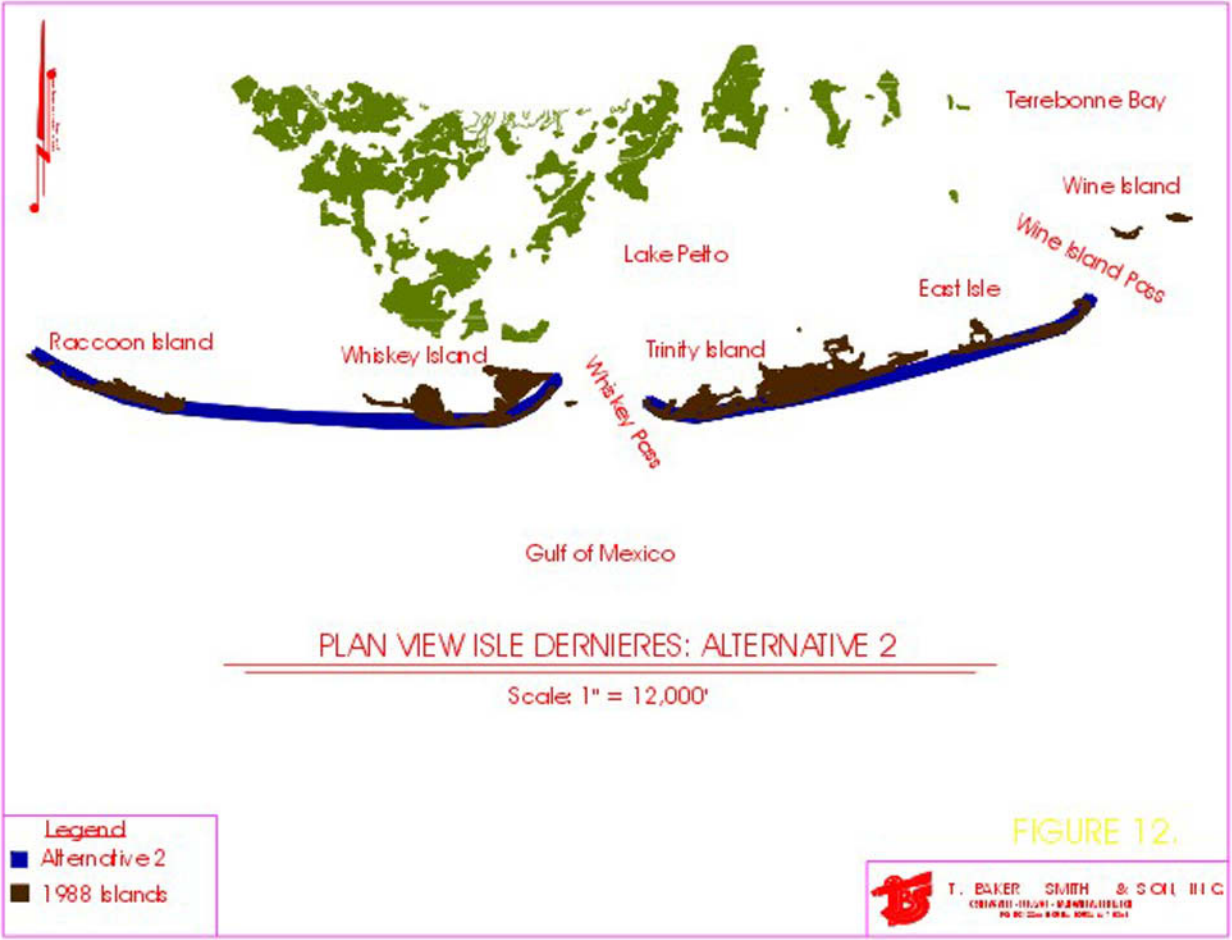


Figure 12. Plan View Isles Dernieres: Alternative 2

Figure 13. Plan View Timbalier Islands: Alternative 1

Figure 14. Plan View Timbalier Islands: Alternative 2

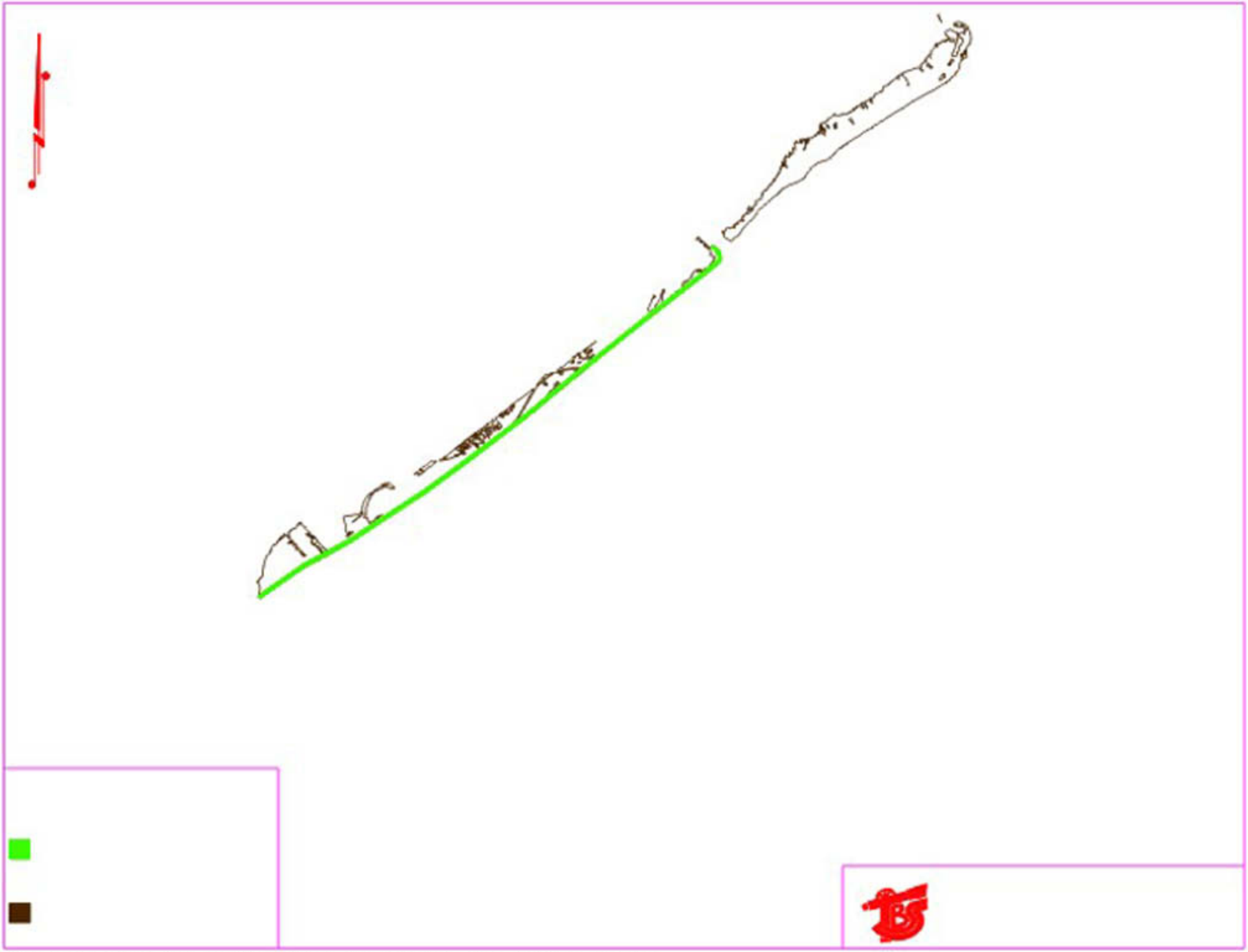


Figure 15. Plan View Caminada-Moreau Headland: Alternatives 1 and 2

Figure 16. Plan View Plaquemines Shoreline: Alternative 1

Figure 17. Plan View Plaquemines Shoreline: Alternative 2

In certain cases, little or no elevation data were available and some assumptions were necessary to account for data gaps. First, existing profiles or spot elevations were sometimes uniformly distributed in areas of similar elevation. Next, in back-barrier areas, a spot elevation of +1.1 ft (msl) was used in low-lying areas, such as the back bay marshes. This is based on a report (Traverse 1988) stating that the Isles Dernieres had an average elevation of 1.1 ft.

In most areas, the alternatives were larger than the existing islands. To provide adequate bathymetric information, the *Louisiana Barrier Island Erosion Study Atlas of Sea-floor Changes* (List *et al.* 1994) was utilized. Bathymetric points were digitized using contours from the atlas in areas adjacent to the island and in tidal inlets. Surfaces were then constructed to calculate the material needed to fill the subaqueous portions of the alternatives. Table 7 shows the net section fill quantities necessary to construct the alternatives.

Table 7. Estimated Net Section Fill Quantities of the Alternatives 1 and 2

Area	**Alternative 1 Historic Condition (yd^3)**	**Alternative 2 Pre-Andrew Conditions (yd^3)**
Isles Dernieres	23.0 million	23.3 million
Timbalier Islands	26.5 million	14.0 million
Caminada-Moreau Headland	885,000	535,000
Grand Isle	N/A	N/A
Plaquemines	42.9 million	17.1 million
Total	**93.3 million**	**54.9 million**

The material needed to construct Alternative 1 is slightly less than Alternative 2 at the Isles Dernieres (23.0 and 23.3 million cubic yards (net section fill), respectively). This is due to Raccoon Island being excluded from the continuous Isles Dernieres chain in Alternative 1. Alternative 1 does not include Raccoon Island for three reasons: 1) there are no direct impacts on oil and gas infrastructure north of the island, 2) wave absorbers will be built to protect the marsh shoreline in northeast Caillou Bay, and 3) the marginal returns to connect the island may exceed the benefits. In Alternative 2, Raccoon Island is included, while letting Whiskey Pass remain open and constructing no project at Wine Island.

In the Timbalier Islands, Alternative 1 requires almost twice as much material as Alternative 2. This is primarily due to the first alternative having a 68% larger cross-section than the second. Also, Alternative 1 reduces the size of Little Pass in order to reduce storm surge and wave propagation through the inlet. Both alternatives close Raccoon Pass (Pinrod Slip), located between Belle Passe and East Timbalier Island. Alternatives 1 and 2 require 26.5 million and 14.0 million cubic yards (net section fill), respectively.

The preliminary quantities calculated for the Caminada-Moreau Headland show that 885,000 cubic yards of native sand are needed to construct the dune and beach systems of Alternative 1. Alternative 2 requires 535,000 cubic yards of additional sand to form continuous dunes and a renourished beach along the shoreline.

As described in Step I, Grand Isle is predicted to experience minimal erosion in the future based on long-term data. Also, a Federal flood protection maintenance program will ensure that adequate beach and dunes exist to protect the local infrastructure. The design elevation at Grand Isle, which the Corps of Engineers constructed for flood protection, is larger than the conceptual alternatives proposed in the Barrier Island Plan. In addition, the low historical erosion rates indicate that Grand Isle is eroding at a significantly smaller rate than other barrier islands in the study area. Therefore, it is not necessary to reconstruct Grand Isle in either of the alternatives. However, it is recommended that Grand Isle have a beach maintenance program for both flood protection and recreational value, based on the positive cost benefit analysis performed by the Corps of Engineers (USACE 1979).

The Plaquemines shoreline, which includes the shoreline from Grande Terre to Sandy Point, requires notable differences in quantities needed to construct the alternatives. Although Alternative 1 is much wider than Alternative 2, most of the quantity difference is due to the reduction, or closing, of non-historical canals and passes. By definition, Alternative 1 only includes historical passes existing at around the 1890's. All jettied or navigational passes remain open. Alternatives 1 and 2 require 42.9 and 17.1 million cubic yards (net section fill), respectively.

The preliminary results indicate that 93.3 and 54.9 million cubic yards (net section fill) of native material are needed to build the design template for Alternatives 1 and 2, respectively. The preliminary cost estimates adjust these values for various maintenance considerations, overfill factors, and incremental increases in the project storm design level.

4.4. Design Methods

The design methods used for the <u>initial</u> construction of the two alternatives are separated into five categories: beach, dunes, marsh platform, coastal structures, and vegetative plantings. Maintenance of the projects will be discussed in Section 5.2. Cost estimates of the wave absorbers are calculated separately from the engineering techniques on the islands, but are included in total cost estimates.

4.4.1. Beach

A preliminary design for beach nourishment, by definition of the National Research Council (NRC 1995), answers the questions of how wide the nourished beach will be after equilibration and how long will the sand will last after placement must be addressed. At the preliminary level, equilibration is assumed to occur instantly. Also, the berm height is assumed to be the same as the native berm height. Other profile characteristics, such as dune design, are not addressed (NRC 1995).

The beach, or berm, for the proposed alternatives is the same. The foreshore slopes from the shoreface at +0.0 feet (msl) elevation to the toe of the dune at +4.0 (msl). The design beach berm will be built on the existing island and will not transgress seaward. Unlike beach nourishment projects elsewhere, the goal is not to restore a beach seaward but to build upon the existing island and maintain a beach that protects the dune and provides intertidal habitat. The design template width is ±300 feet, giving the berm a slope of 1:75. The natural slope varies along the coast, but is on the order of 1:100.

Losses can be expected due to reshaping of the beach as waves move sand particles throughout the nearshore. Silts and clays will be removed in the construction phase through a winnowing process. Finer grain sands will move offshore within the depth of closure, which for study purposes is between -14.8 ft (msl). These losses and movement of sediment are accounted for in the overfill factors discussed in Section 3.0. The beaches are to be constructed using unconfined fill.

The initial beach fill volume also has a coefficient which accounts for the lateral spreading of beach fill due to longshore transport. The coefficient provides an estimation of the percentage of sand to be retained within the boundaries of a beach fill as a function of time. Sand moves laterally over time and, assuming no end structures exist, losses to inlets will eventually take place. A method determined by Dean and Yoo (1993) provides an estimation of the percentage of sand retained within the length of fill. Figure 18 shows the evolutionary process of the lateral equilibration. For this analysis, the inverse of the percentage of sand to be retained was multiplied by the volume of sand added to the beach fill. This added volume is estimated to offset the lateral shifting and losses of sand due to the oversteepened profile.

An advance fill template is an addition of sand to the design template that accounts for losses due to coastal processes. Output of the wave and hydrological modeling in Step J predicts the influence of the management alternatives on coastal resources. The model results show that for each alternative an island with a specific height, width, and length is necessary to achieve the best overall benefits. Therefore, the positive changes on coastal resources are dependent on that particular design, and nothing less, to achieve maximum benefits. By including an advanced fill in the nourishment of the island, the dimensions of the alternatives can be maintained until the first maintenance cycle.

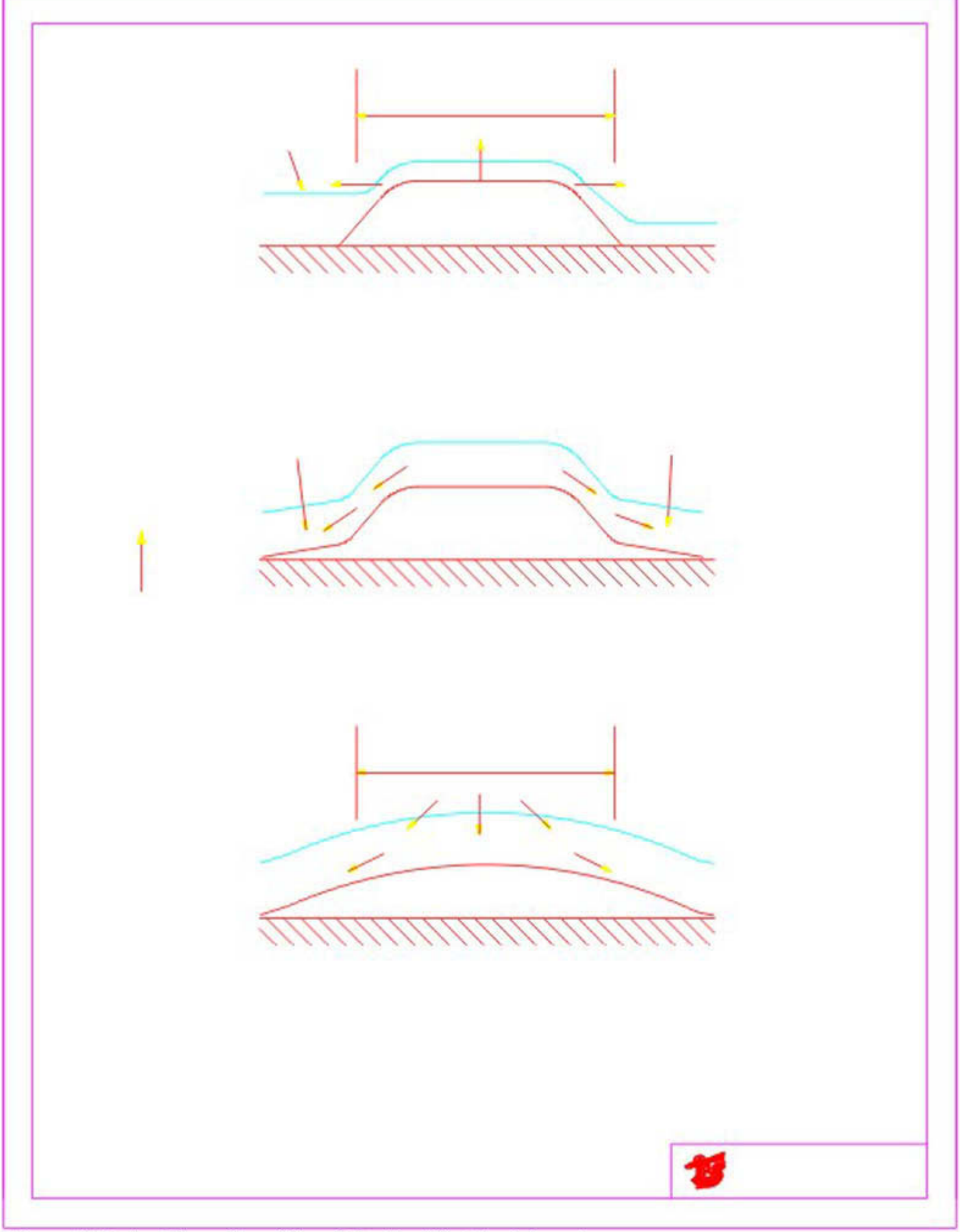


Figure 18. Lateral Spreading of Beach Profile After Nourishment

To calculate the advance fill quantities, the sediment budget for each of the four sub-areas was determined per unit length of shoreline. To do this, information from both the *USGS Sea-floor Change and Shoreline Change Atlases* were used (List *et al.* 1994; Williams *et al.* 1992). The method involves taking the average volumetric erosion rate on the gulf side of the shoreline and dividing this by the shoreline length. The Phase 1 Barrier Shoreline has a net sediment deficit, therefore, there is an annual volume of material lost per unit length of shoreline. These volumetric losses are shown in Table 8.

Table 8. Annual Volumetric Losses

Location	Volume Loss/Unit Length of Shoreline/Year (yd^3/ft/yr)
Isles Dernieres	11.2
Timbalier Islands	22.9
Caminada-Moreau Headland	80.3
Plaquemines Shoreline	28.4

An alternative method is to take the average shoreline recession rate and convert that to cubic yards of material lost, using the equilibrium beach theory developed by Bruun (1954) and Dean (1977, 1991). Considering the sediment data used to calculate overfill factors, the equilibrium beach method produces higher volumetric losses than using the rates shown in Table 8. Estimated volumes using the equilibrium profile method are higher, possibly due to the assumptions made using limited sediment data in the nearshore, foreshore, and borrow sites to account for equilibrium beach volumes. Another possibility is the inability of the equilibrium profile theory to account for hard clay foundation found at the islands. These areas contain hard-packed clays and would not conform to wave reshaping as would sand.

Prior to actual design, engineering surveys and a thorough geotechnical investigation must be completed for unconfined beach fills on these islands. If the volumes estimated using the equilibrium beach theory are indeed valid, then the quantities estimated in the maintenance of the projects may have to be increased to account for underestimates of the sediment budget approach used in this study.

For this analysis, the volume of beach fill needed is based on the following: 1) the construction template volumes for a 300 foot wide beach, 2) advanced fill due to anticipated erosion within maintenance cycles using the sediment budget approach, 3) advanced fill to compensate for lateral spreading losses, and 4) an overfill factor to account for losses due to differences in the native and borrow sediments. Figure 19 illustrates the components comprising the beach fill template described in this section.

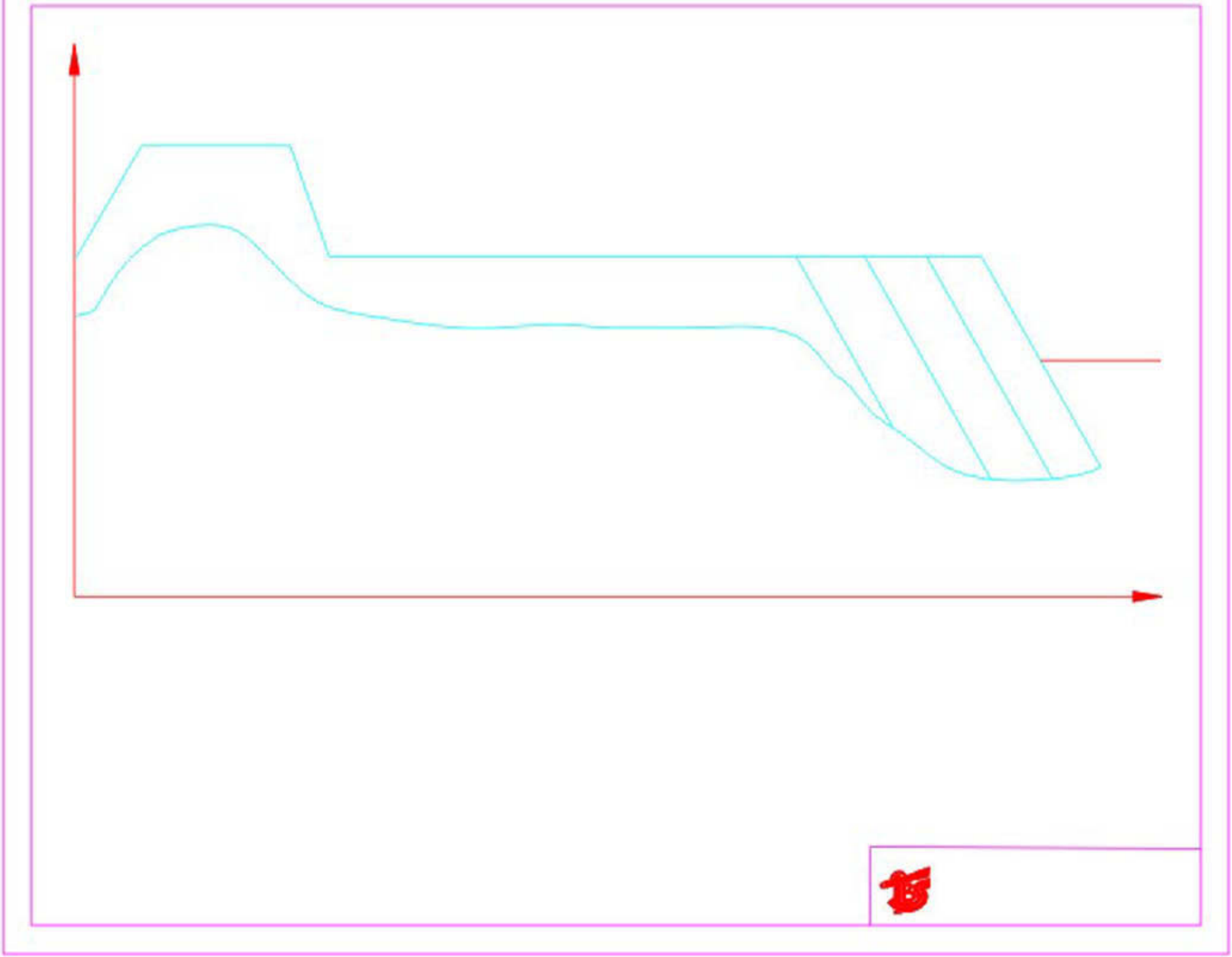


Figure 19. Real Beach Fill Placement Quantities

4.4.2. Dune

Dune design is a complex effort to maximize flood protection, prevent overwashing, and reduce the frequency of maintenance. The preliminary description of the alternatives states that the dune height is +9.0 ft (msl) and +6.6 ft (msl) for Alternatives 1 and 2, respectively. These heights were included in the numerical modeling and subsequent assessments of the alternatives in Step J.

Variations of the dune height have been incorporated into the engineering analysis for cost analysis purposes. A larger dune height will require less maintenance, but the initial and maintenance costs may be greater than building and frequently maintaining a smaller dune height. In the analysis, three dune heights were assessed based on their probability of exceedance. Events with a 50% probability of exceeding the return period were chosen for dune maintenance intervals of 5, 10, and 15 years. For example, a storm with a return period of approximately 8 years, has a 50 percent chance of being exceeded in 5 years, while a 15-year return period event has a 50 percent chance of being exceeded in 10 years. Table 9 lists the return period events used to determine the dune height.

Table 9. Storm Surge Elevations for Events with a 50% Probability of Exceedance for 30, 15, 10, and 5 Years, Respectively

Return Period (years)	Isles Dernieres	Timbalier Islands	Caminada-Moreau Headland	Plaquemines
44 yr	10.9	10.9	8.3	8.3
22 yr	7.9	7.9	6.9	6.9
15 yr	6.0	6.0	6.0	6.0
8 yr	2.9	2.9	4.4	4.4

The assumption used in this analysis is that the dune will have to undergo total reconstruction during the dune maintenance cycle. The objective is to determine whether it is more cost effective to build a larger initial project and rebuild it less often, or more frequently maintain a smaller project.

Another primary assumption is that the islands will continue to erode at their historical (100-year) rates, despite the closing of breaches, restoration of a sandy nearshore, and reduction in overwash frequency due to higher, continuous dunes. Reductions in erosion rates are likely to occur but have not been incorporated in this analysis.

4.4.3. Marsh Platform

The marsh platform is the widest part of the island cross section, ranging from 840-1,610 feet for Alternatives 1 and 2 respectively. The platform begins at the backside of the dune at a +5.0 feet (msl) and slopes to a +1.5 feet (msl) at the bayside shoreline. Vegetation is planted on the platform. Natural runoff and tidal scour are allowed to shape the platform, forming tidal pools and meanders into the island.

Vegetation on the marsh platform ranges from dune/swale habitat to saline marsh in the intertidal shoals formed from the effluent settling beyond the dredging spillboxes. The marsh platform will not have a maintenance program. The intent is for the island to continue to migrate landward as sand is transported landward due to sea-level rise and occasional overwash, similar to that occurring at the western end of Timbalier Island.

4.4.4. Coastal Structures

As described in Section 4.2.3, various coastal structures have been used in the Phase 1 Study Area to reduce erosion rates, stabilize shorelines, and maintain navigation channels. Coastal structures alone do not provide sand to a beach, they only redistribute available sand by causing accretion in one area at the expense of erosion in another area. However, the use of coastal structures in conjunction with the alternatives could reduce the cost of maintenance. The following sub-sections will describe the types and locations of recommended coastal structures in the Phase 1 Study Area. The initial investment cost and subsequent maintenance costs will be quantified in Sections 5.1 and 5.2.

4.4.4.1. Isles Dernieres

A terminal groin is recommended at the western extent of the Isles Dernieres (Whiskey Island - Alternative 1; Raccoon Island - Alternative 2). Terminal groins are rock structures usually built perpendicular to the shoreline at the end of a beach restoration project. For the Phase 1 Study Area, these structures are recommended in areas adjacent to major inlets or where downdrift erosion is not a concern. The purpose of the groins is to retain sand moving alongshore that would otherwise leave the system. Capturing westward moving sand can offset erosion rates and can be used for future maintenance of the islands. Downdrift shorelines at Marsh Island will not experience adverse impacts. Marsh Island’s attachment to the mainland and the large open water area dividing it will minimize the downdrift effects of the terminal groin.

A series of segmented offshore breakwaters should be used where tidal inlets have been closed (Whiskey Pass - Alternative 1, Coupe Colin - Alternative 2, New Cut - both). Offshore segmented breakwaters are structures located parallel to the shoreline within the nearshore region. They protect the shoreline behind them by absorbing and reducing the wave energy transmitted to the beach. If an adequate sediment supply is available, a salient (widened section of beach) can form. Sediment accumulates due to the reduction in longshore transport rates, which are a function of wave height and direction.

Newly closed inlets will need stabilization until the system reaches equilibrium. The tidal channels located perpendicular to the island allow waves to break closer to the shoreline creating a vulnerable section of shoreline. A series of segmented offshore breakwaters would slow longshore transport and promote accretion during moderate wave conditions. Erosion during storm events could be reduced by the breakwaters as well. Downdrift beaches are predicted to experience erosion, but it is not possible to quantify if the change in erosion rates would increase as a result of the breakwaters or decrease as a result of the inlet closure. Either way, a beach nourishment program should accompany the project and downdrift erosion should be offset in the final engineering design.

Wine Island is surrounded by rocks serving as containment for dredge fill and protection from future erosion. This project has proven successful and, with the expansion of the island as part of Alternative 1, should be used for future containment. Wine Island is located in a high energy environment and is detached from an updrift sand source. The island provides nesting ground for many species of birds, including the Brown Pelican. A rock revetment built similar to the beneficial use project would expand the island and reduce the need for maintenance.

4.4.4.2. Timbalier Islands

A terminal groin is recommended on the western end of Timbalier Island. The groin is designed to capture sediment but allow bypassing beyond the toe depth of the structure. This structural technique offers several advantages. First, the groin captures sediment moving into Cat Island Pass. This is significant because the island has historically moved laterally to the west due to longshore transport. By creating a sand trap, sediment can accumulate in front of the island rather than depositing in the Pass. Second, sediment for future maintenance of the Timbalier Islands may be partially offset by the sand captured by the groin. Sand could potentially be mined from the sand fillet and pumped along the beach. The close proximity of the borrow site would reduce unit dredging prices. Finally, the Corps of Engineers dredges the Houma Navigation Canal at Cat Island Pass on an average of every 2.2 years. Construction of the groin would reduce the frequency for dredging the channel and reduce the costs of further realignment as proposed in 1997.

Construction of segmented offshore breakwaters on the eastern portion of Timbalier Island is recommended. The breakwaters would slow the erosion of the eastern shoreline, which is currently fragmented and breached. Sand bypassing Little Pass would accumulate on the eastern end and reduce the frequency of renourishment. Breakwaters are recommend from the eastern tip of Timbalier Island to the tip of the existing rocks placed by the Louisiana Department of Transportation and Development (LADOTD). This protects the weakest section of the island and would work well with the proposed groin on the west end.

The negative aspects of the proposed groin and breakwater are that material bypassing Cat Island Pass would be reduced or halted. Potentially, this could reverse the historical accretion trend along the eastern section of the Isles Dernieres. This localized impact may be offset by the savings in dredging of the Houma Navigational Canal. It may also allow more beneficial use of dredge material by placing sand on East Isle instead of the current placement method on offshore bars several miles from the island.

East Timbalier Island is currently surrounded by offshore breakwaters and revetments. CWPPRA projects TE-25 and TE-30 will include shoreline stabilization along portions of the island. The closure of Raccoon Pass should be implemented by the continuation of gulf shoreline stabilization at East Timbalier Island. Instead of a detached breakwater, an onshore rock revetment should be used to serve as front containment of fill and provide protection against further erosion.

4.4.4.3. Caminada-Moreau Headland

The Caminada-Moreau Headland is a rapidly eroding area that, on the surface, warrants shore protection. With an average shoreline erosion rate of 44 ft/yr over 11 miles, the maintenance cost for a beach fill project is prohibitive. There are two reasons for this. First, the shoreline erosion occurs east of the Belle Passe jetties. Second, sediment leaving the shoreline has historically provided sand to the Timbalier Islands, as well as to Grand Isle.

If sand is added to the systems by way of the restoration projects, the systemic need for sand from the Bayou Lafourche Headland diminishes. Sand is already being trapped at the Belle Passe jetties, reducing the available sediment to East Timbalier Island and eroding the island. The removal of the jetties is neither warranted nor feasible.

Those areas along the headland that are susceptible to flooding or saltwater intrusion should be fortified using hardened structures. Breakwaters could be used, but they are more expensive than placing rocks directly on the shoreline to form a revetment. “Rocking” the entire coast is not desirable and is cost prohibitive. Critical sections of shoreline should be armored, near Fourchon for example, similar to that at Timbalier Island.

Localized efforts at armoring or constructing breakwaters at Grand Isle should be avoided. Historically, jetties, groins, and breakwaters have been constructed to combat the erosion on an island that has remained relatively stable over the last 100 years. Construction of the jetties on both ends of the island confines the movement of material and has caused downdrift erosion at Grand Isle and at Grande Terre. Construction of breakwaters and groins in localized areas causes downdrift erosion to other areas and should be avoided. The effect of breakwaters on the bayside of the island have not been fully quantified, but the fetch in this region is minimal and wave erosion may not be the primary factor eroding the shoreline. There has been no quantifiable evidence that the breakwaters constructed are promoting accretion, and thereby, justify their cost. These breakwaters should serve as a demonstration project when future expansion of breakwaters is recommended along the bay shorelines.

4.4.4.4. Plaquemines

The closure of Coupe Abel at Grande Terre (Alternative 1) warrants some consideration of building a breakwater. The closure of this inlet into Barataria Bay would create a vulnerable area on the shoreline that may need to be stabilized, similar to the recommendation at New Cut. Although some downdrift erosion could be expected, the *USGS Study Atlas of Shoreline Changes in Louisiana* (List *et al.* 1994) shows little accretional deposits where sediment would accumulate as tidal shoals.

Similar closures of breaches and inlets under Alternative 1 are not recommended for stabilization due to the presence of small bays and subsequent tidal flow through the inlets. Temporary stabilization using geotextile tubes could potentially be used in these areas rather than rock structures.

4.4.4.5. Wave Absorbers

Wave absorbers were included as part of Alternative 1, described in Step I. These structures are essentially segmented offshore breakwaters located in the interior bays. The purpose of the wave absorbers is to augment the effects of the barrier islands by dampening locally generated waves in the bays, thus reducing erosion of saline marsh. The wave absorbers are constructed from riprap for ease of construction and to minimize costs.

Conceptually, the wave absorbers will not hinder exchange of sediments or circulation of water between the marsh and the bays. Thus, the breakwaters are not continuous and are situated in the bays rather than on the marsh shoreline. An exposure ratio (fraction of shoreline directly exposed to wave energy) of 33% was chosen to significantly reduce wave energy acting on the marsh profile. At this level of protection, over half of the wave energy acting upon the shoreline is dampened while still permitting tidal exchange between the bay and marsh.

Analytical models (See Step B) are available to predict sand shoreline changes, but were not used due to the nature of the soil in the bays and vegetation factors that could not be adequately addressed by a shoreline change model. There may be some use for such an analysis in final design or in a demonstration project in an isolated area.

Discussions with biologists, engineers, and coastal scientists, as well as using empirical relationships from other segmented offshore breakwater projects led to the preliminary design of a wave absorber 300 ft. wide with a gap width of 150 ft. The structures are to be placed along a -4.0 ft. depth contour. Actual placement locations, size, and spacing may vary in the final design in order to maximize wave dampening in critical marsh types.

In all, 570 wave absorbers are included as part of Alternative 1. Table 10 lists the location and number of the breakwaters. Figure 20 shows a typical section of a wave absorbers and Figures 21-23 illustrate a typical plan view in each basin. Appendix A contains the design procedure and discusses the assumptions made in the preliminary design of the wave absorbers.

The wave absorber configuration, as part of Alternative 1, was placed in the STWAVE wave model for analysis of the alternatives. The reduction in wave energy as a function of both the restored Alternative 1 barrier island configuration and the placement of the wave absorbers along the bay shoreline is discussed in detail in the Step J report.

Table 10. Location of Wave Absorbers (Alternative 1)

Location	Sub-area	Number of Wave Absorbers
Caillou Bay	Isles Dernieres	95
Terrebonne Bay (west)	Isles Dernieres	62
Terrebonne Bay (east)	Timbalier	42
Timbalier Bay	Timbalier	194
Barataria Bay	Plaquemines	177
Total		570

4.4.4.6. Feeder Beach Considerations

Any structural measure that may be used will influence both the updrift and downdrift shoreline. Structures that prevent movement of material create a reduction of sediment downdrift causing increased erosion elsewhere. A feeder beach or bar is recommended in conjunction where coastal structures, such as breakwaters or revetments, may be used to offset down drift erosion. The specific design for the feeder beach, as well as for the breakwater and revetment designs, are site specific and should be investigated in more detail during final engineering design.

4.4.5. Vegetative Plantings

Vegetation of the dunes and marsh platform is needed to stabilize the newly placed fill and establish viable vegetated wetland habitat. Various species of plants can be used on the islands and further consideration of plant selection should be made on a site-specific basis. For this analysis, landscape architects and biologists were consulted as to general costs and species for vegetating the barrier islands. It is assumed that the dunes will require hand planting of marshhay cordgrass at approximately one plant per ten square yards. At a cost of $7.00/plant in place, this method will cost $3,388/acre.

The marsh platform will be aerially seeded using mixtures of seeds and fertilizer. The aerial planting cost is estimated at $150/acre based on previous projects done on East Isle and Timbalier Island. Planting layouts will be refined during the final design, incorporating more detailed cost and quantity information.

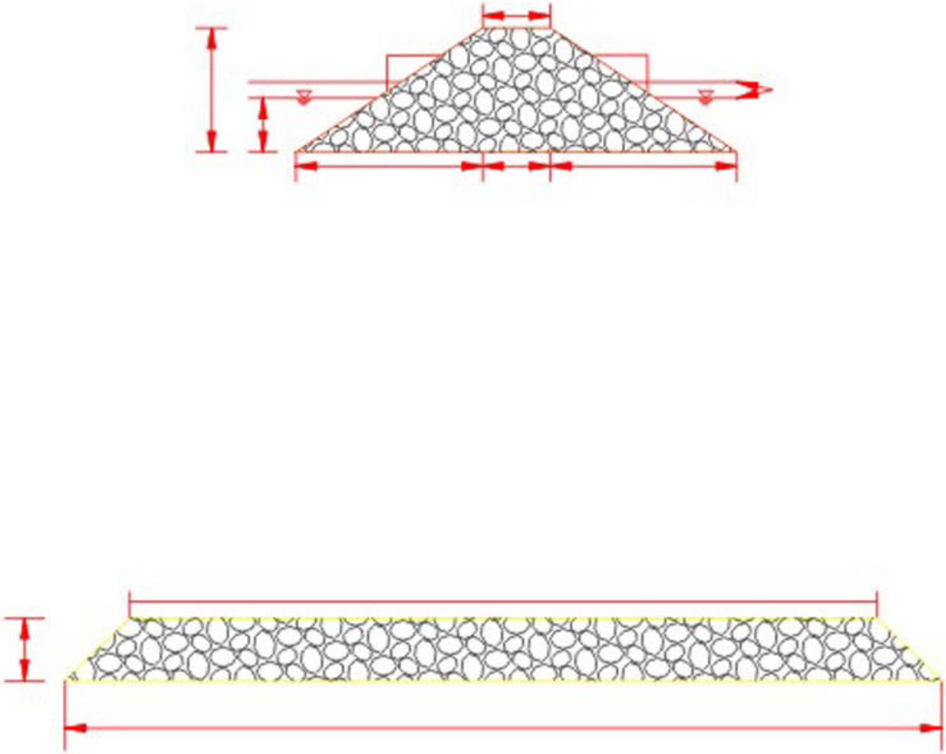


Figure 20.Typical Section/Profile Wave Absorbers

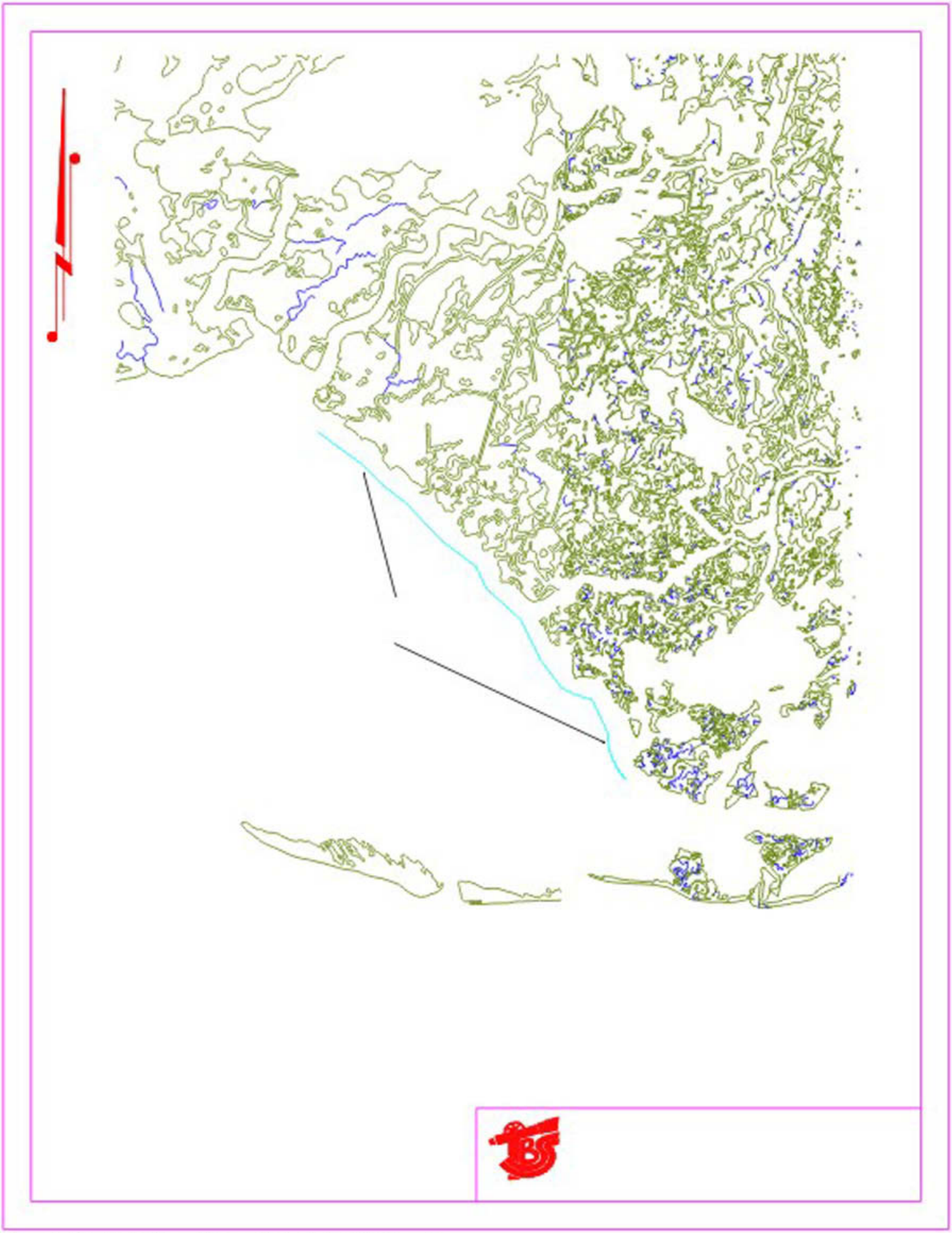


Figure 21. Plan View Wave Absorbers: Caillou Bay

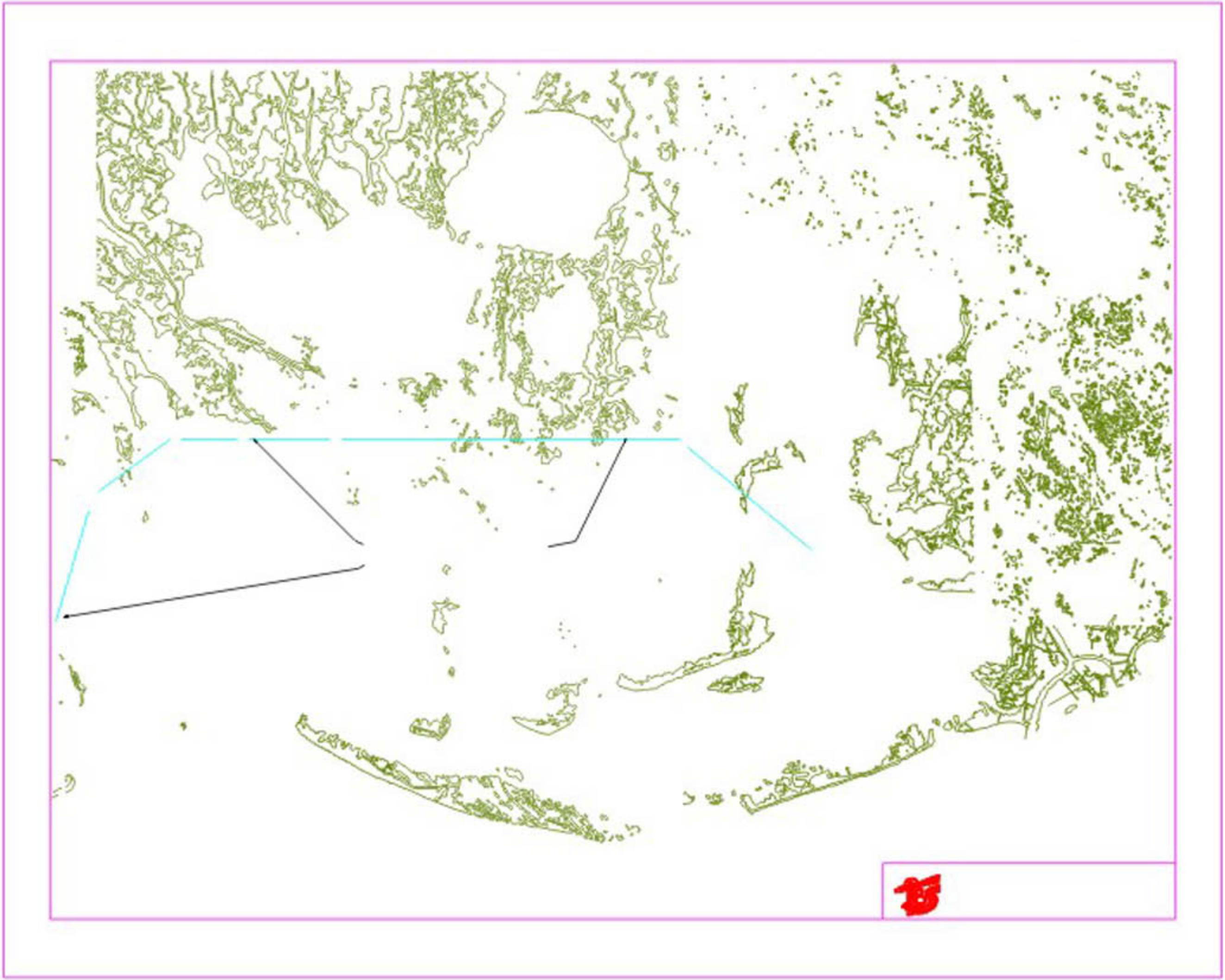


Figure 22. Plan View Wave Absorbers: Terrebonne/Timbalier Bay

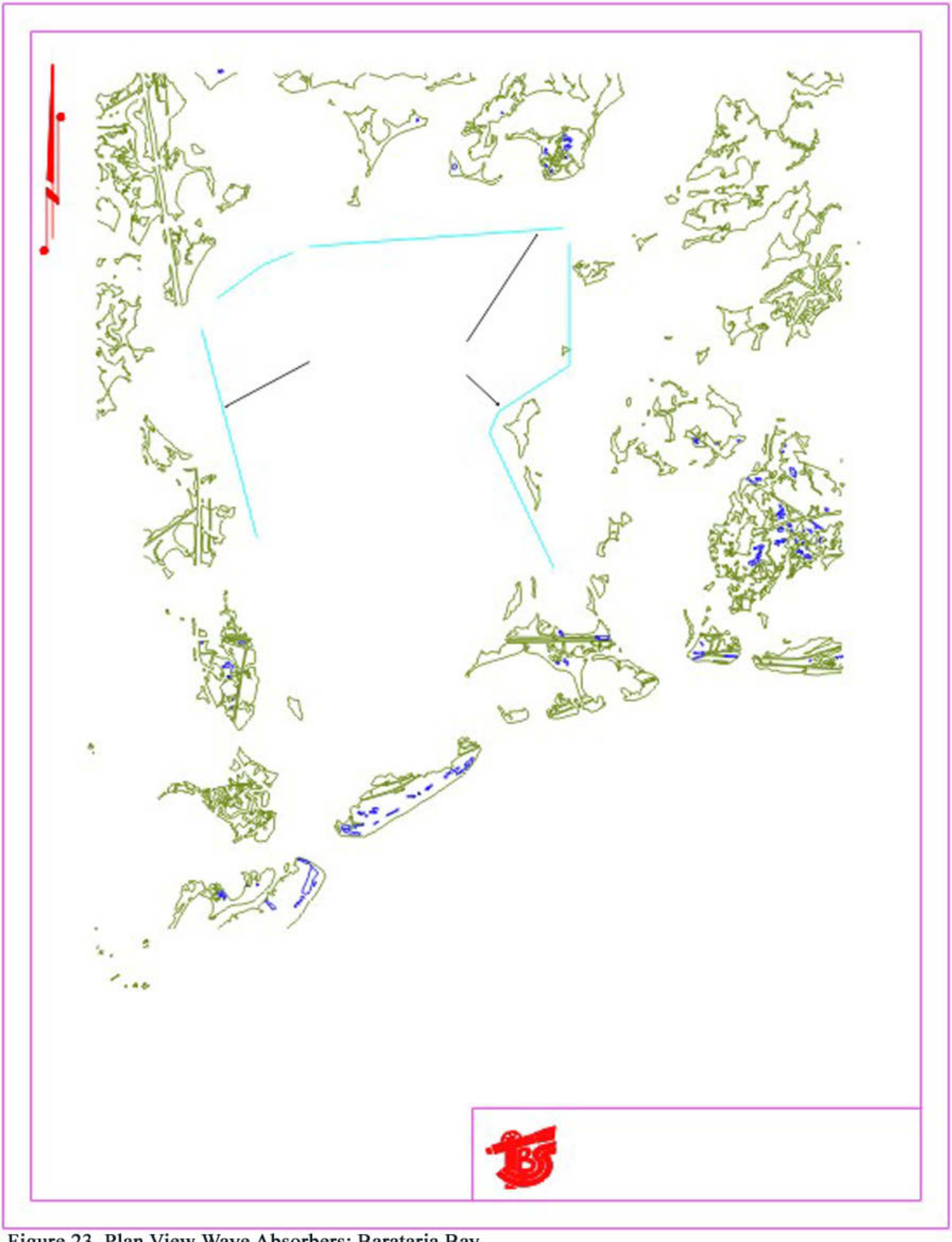


Figure 23. Plan View Wave Absorbers: Barataria Bay

4.5. Engineering Techniques

The engineering techniques used in this analysis are broad based approaches that provide cost estimates for initial and future maintenance of projects only at the islands. Maintenance of the projects assumes the alternatives are preserved to the initial design template. The design template includes a 300 foot wide beach, an elevated dune of variable width, and a marsh platform extending to where the average island width is ±1,970 ft and ±1,230 ft for Alternatives 1 and 2 respectively. The islands will change and migrate, therefore the actual engineering design must be updated accordingly.

Three engineering techniques at the islands are evaluated for Alternatives 1 and 2: 1) sand only, 2) sand and revetments, and 3) sand and combinations of structures.

4.5.1. Sand Only

The sand only option uses in situ and borrow material to construct and maintain the alternatives. The primary advantage of this project is the restoration of the projects using natural material that adjusts to the environmental conditions. The dunes and marsh platform are vegetated, while the beach berm nourishes the nearshore and serves as the sacrificial portion of the island. The objective is to renourish the beach at five year intervals, while rebuilding the dunes at designated intervals, depending on their anticipated design life.

Three dune heights were evaluated using soft-structure-only techniques. These correspond to the water level height anticipated for 8-, 15-, and 22-year return period events. These correspond to a 50% probability of exceedance in 5-, 10-, and 15- years respectably. Therefore, it is assumed that the dune structure will undergo major reconstruction during those years of 50% probability of exceedance. For example, the dune designed for a 15-year return period will be rebuilt at years 10 and 20. The beach will be renourished for this, and all other techniques, at years 5, 10, 15, 20, and 25. It is assumed that dune restoration will accompany beach renourishment in years 10 and 20, thus eliminating the need for two separate projects. Based on these maintenance cycles, the cost to maintain the design template for years will be estimated.

To calculate the dune heights, the Phase 1 Study Area was divided into two parts. Suhayda (1991) generated surge frequency curves for East Timbalier Island. These curves are assumed valid for the Isles Dernieres and the Timbalier Islands. The Corps of Engineers (1972) generated the surge frequency curves for Grand Isle. These are used to determine the design water levels for the Plaquemines shoreline and the Caminada-Moreau Headland.

Wave data was derived from the Wave Information Study (WIS) Gulf Stations 19 and 20. The return frequency for the return period events was found, and wave runup calculations were calculated for a sloped beach using the Automated Coastal Engineering System (ACES). Wave runup calculations are important to the attempt to prevent wave overtopping of the dunes. However, the flooding caused by overtopping is of lesser significance due to the lack of homes and other infrastructure on the islands themselves. Prevention of overtopping is strictly a maintenance factor in the design process and is not intended to eliminate overtopping entirely.

Daily tidal levels were added to the water level design to account for surge heights occurring during high tide. Also, a 30-year relative sea level rise factor was also added to account for subsidence and global sea level rise. A subsidence rate of 1 cm/year (0.4 in/yr) is assumed (See Section 2.1.2.2). Table 11 shows the water levels used in the dune height analysis. Figures 24-26 show the typical design section options for the sand-only techniques in each sub-area.

Table 11. Design Water Levels

	Isles Dernieres	**Timbalier Islands**	**Caminada-Moreau Headland**	**Plaquemines**
Design Water Level				
Astronomical tidal amplitude ft)	0.7	0.7	0.7	0.7
Relative sea level rise (0.03 ft/yr)	1.0	1.0	1.0	1.0
Storm surge (ft):				
44 yr	10.9	10.9	8.3	8.3
22 yr	7.9	7.9	6.9	6.9
15 yr	6.0	6.0	6.0	6.0
8 yr	2.9	2.9	4.4	4.4
Wave runup (ft):				
44 yr	2.9	2.9	3.2	3.2
22 yr	2.7	2.7	3.0	3.0
15 yr	2.6	2.6	2.9	2.9
8 yr	2.4	2.4	2.6	2.6
Total (ft):				
30 yr design	15.5	15.5	13.2	13.2
15 yr design	12.3	12.3	11.6	11.6
10 yr design	10.3	10.3	10.6	10.6
5 yr design	7.0	7.0	8.7	8.7

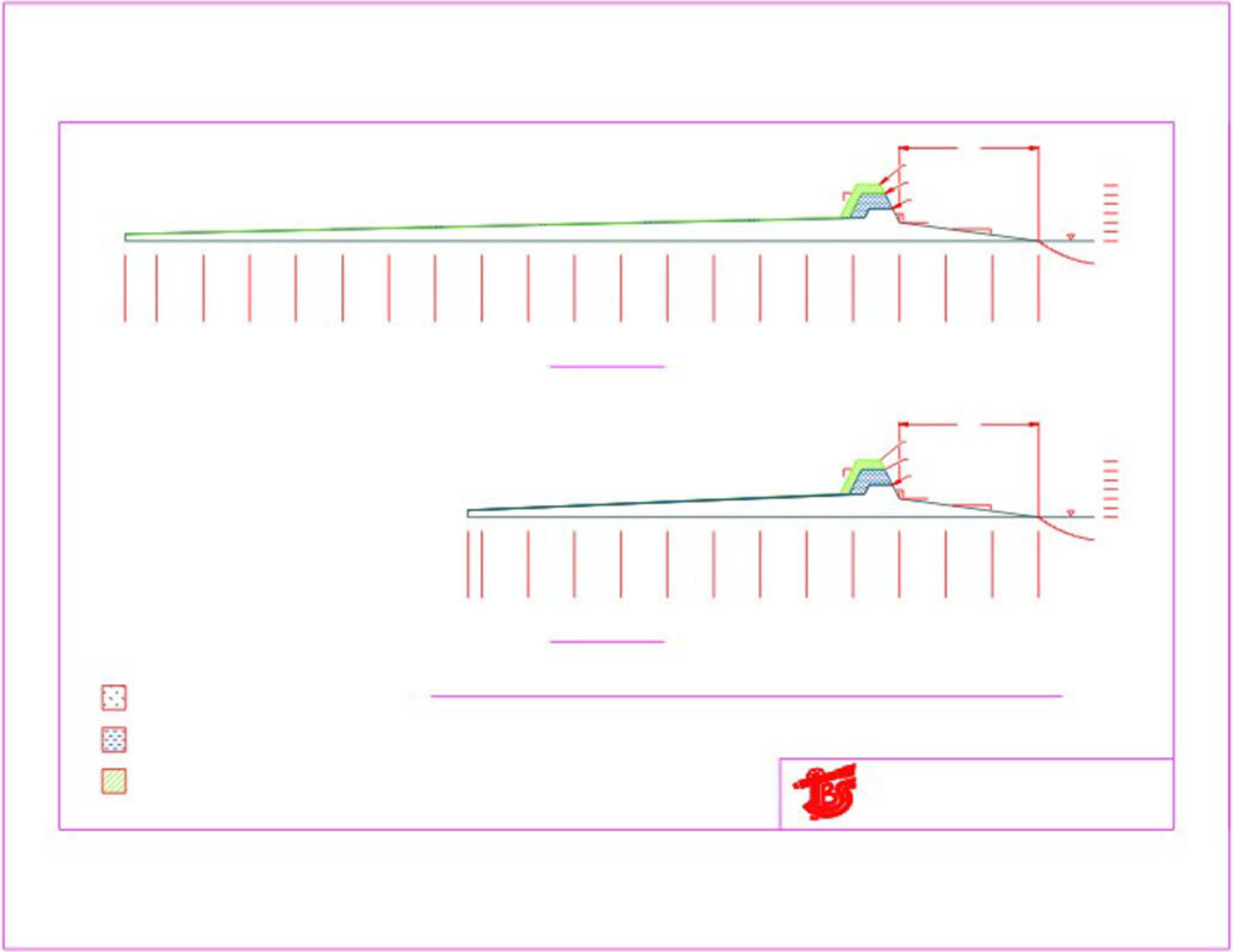


Figure 24.Typical Sections: Isles Dernieres and Timbalier Islands

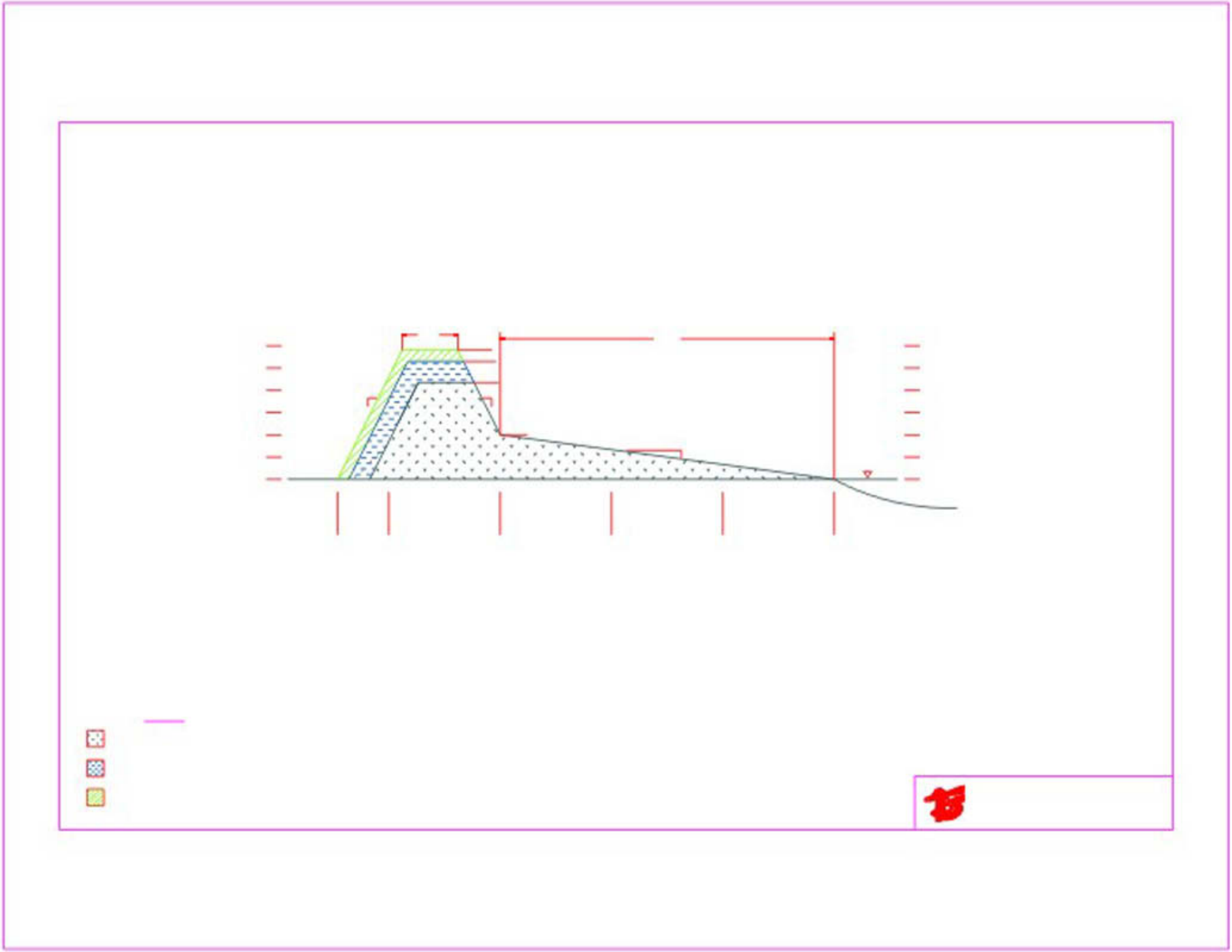


Figure 25.Typical Sections: Caminada-Moreau Headland

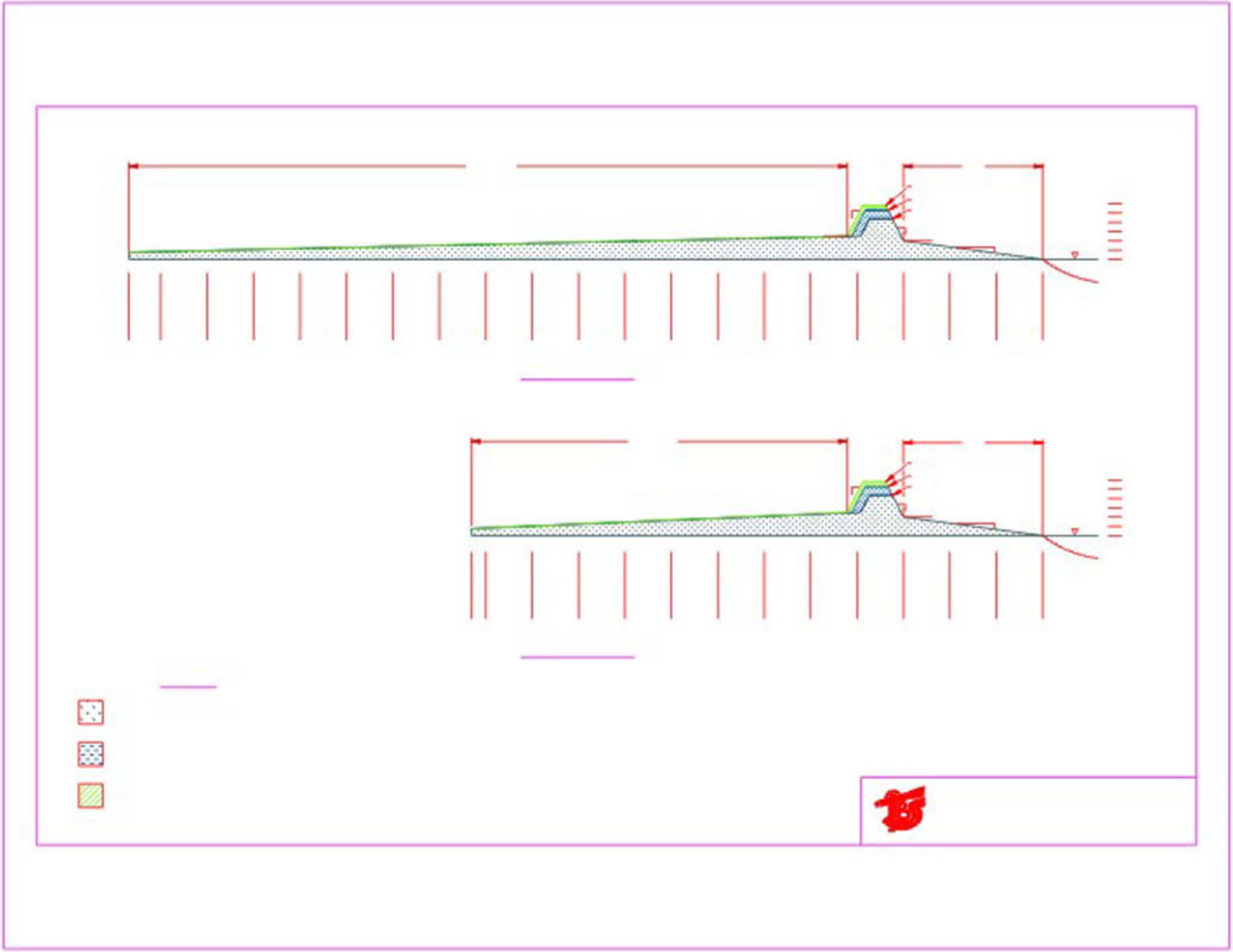


Figure 26.Typical Sections: Plaquemines Shoreline

4.5.2. Revetment Option

The revetment option involves construction of the dune and marsh platform using in situ and borrow material, while replacing the beach berm with a rubble mound revetment. The revetment serves to protect the dune slope from wave attack and eliminate maintenance costs for beach renourishment. Rubble mound structures do not function as a beach, as this component would be replaced by rocks.

The revetment is to be constructed using graded riprap as shown in Figures 27-29. This is recommended based on experience and success of similar projects in the Phase 1 Study Area, including Timbalier Island, Wine Island, and East Timbalier Island. In addition, the revetment is semi-flexible, allowing settlement and minor damages while remaining functional. The revetment design will include armor stone, layer stones, and filter cloth. Settling is expected to occur, but can be minimized due to the placement of a sand and stone underlayer with the filter cloth. During final design, soil borings at the proposed sites are needed for further calculation of settling to avoid improper construction and unforeseen cost increases.

The revetments are built with a 1:2 slope to an elevation preventing wave overtopping of a storm with an 8-year return period. Larger design heights are cost prohibitive and exceed +12 feet (msl) elevations. The dune width was increased from that used in the sand-only technique to account for possible overwashing or channelization. The revetment will adjust if minor damages occur. An estimate of the percent damage is included using cover layer damage for various armor types listed in USACE (1984).

The Isles Dernieres and Timbalier Island design sections are the same, with a 300-foot wide dune built to a +11.1 ft (msl) elevation. The marsh platform width is approximately the same as the sand only width. The Caminada-Moreau and Plaquemines revetment cross-sections are similar. Each has a 300 ft. dune built to an elevation of +13.5 ft (msl). The Caminada-Moreau Headland does not build a marsh platform, so the dune slopes to the existing marsh elevation. The Plaquemines shoreline has approximately the same marsh platform width as the sand-only option. Figures 27-29 illustrate the typical sections for each sub-area’s revetment option. Appendix B contains the design calculations used in the preliminary design.

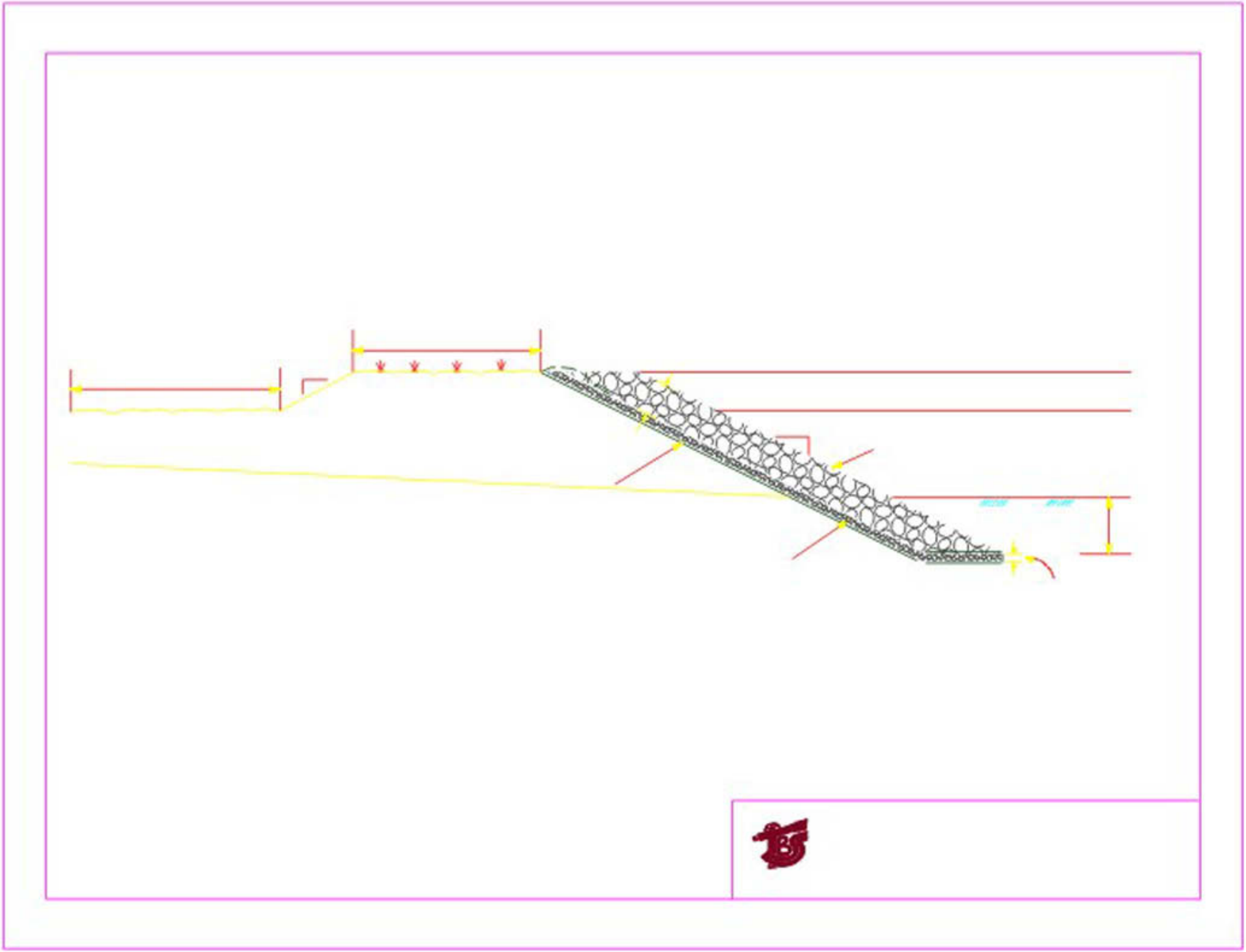


Figure 27.Typical Section Rubble Mound Revetment - Isles Dernieres/Timbalier Islands

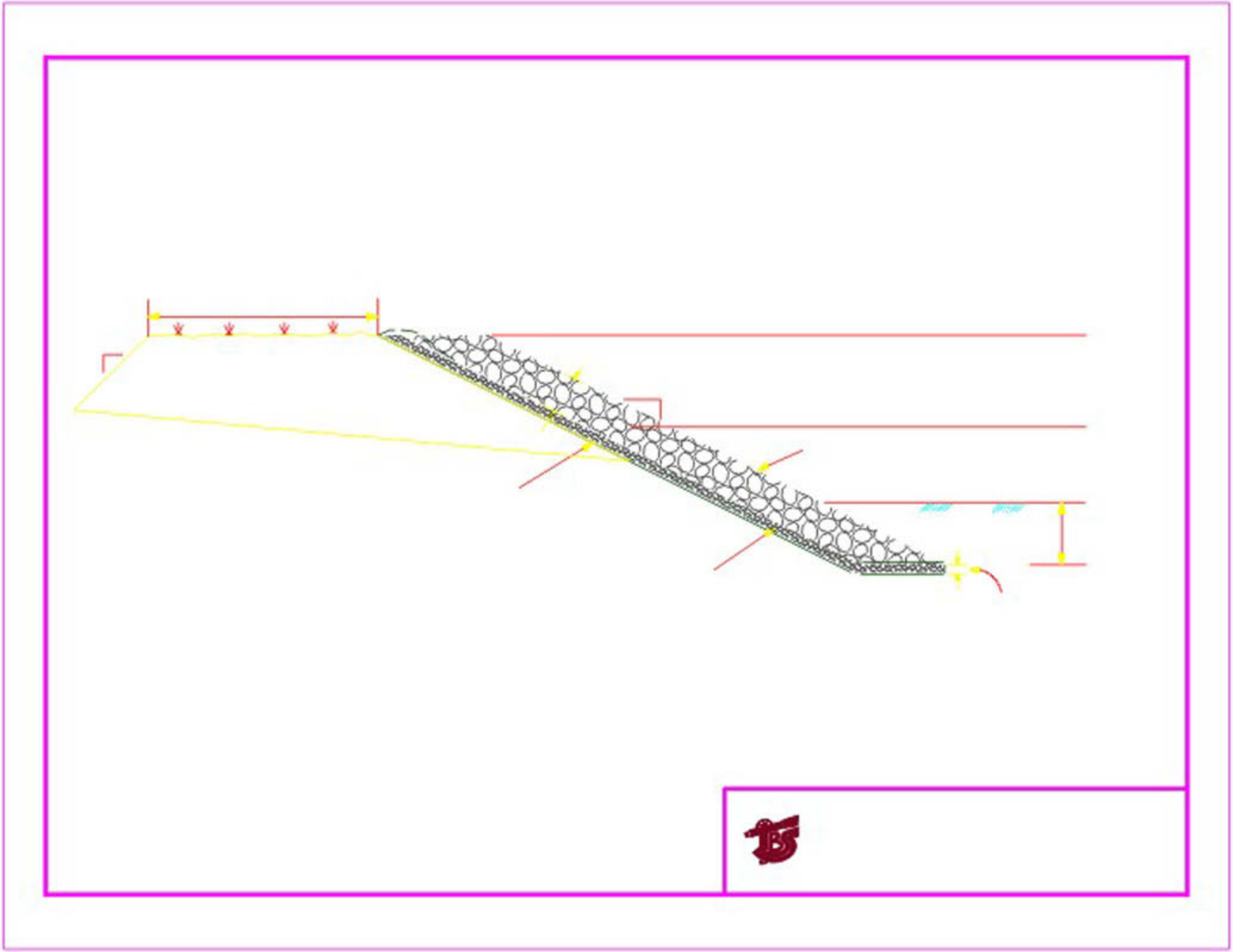


Figure 28. Typical Section Rubble Mound Revetment - Caminada-Moreau Headland

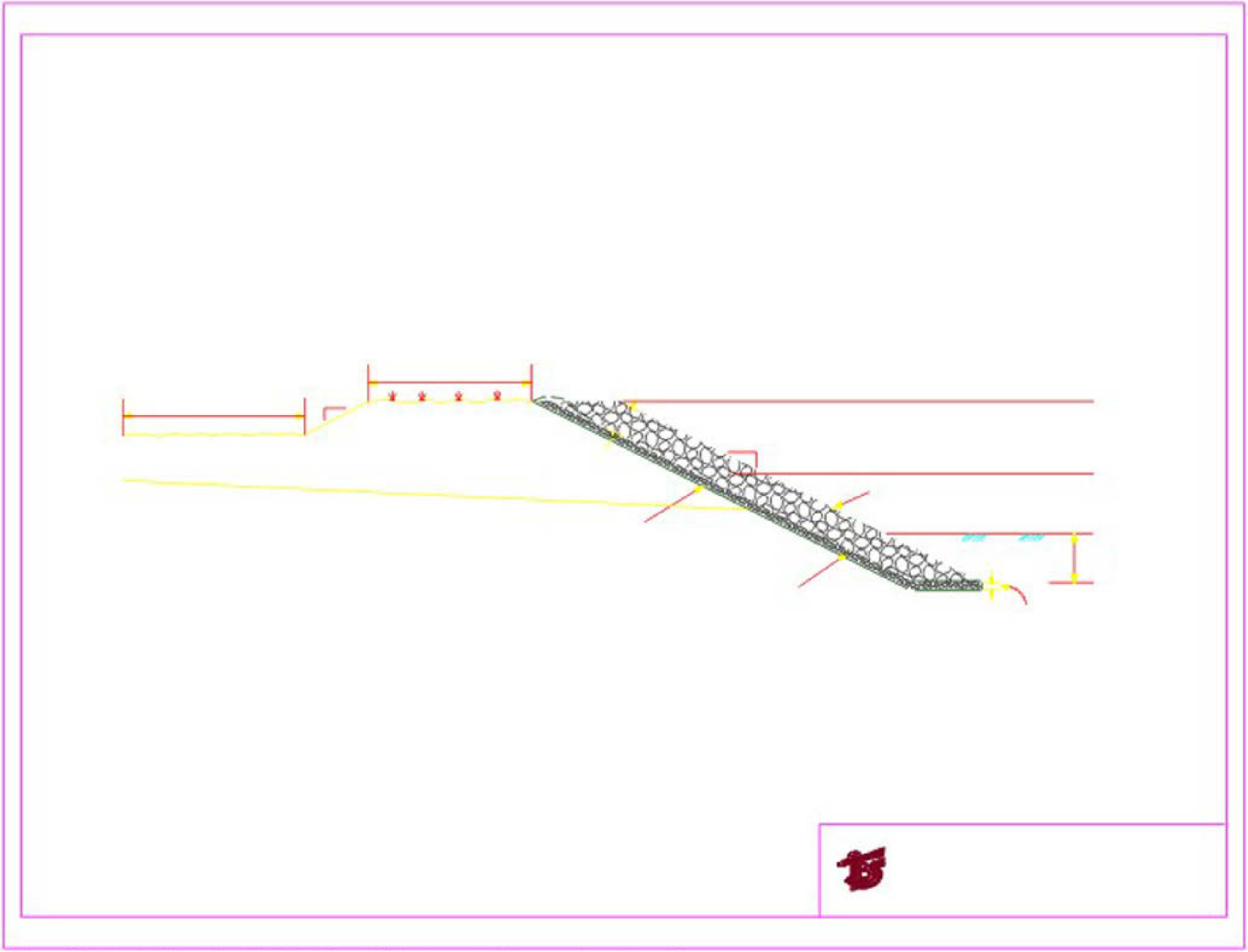


Figure 29.Typical Section Rubble Mound Revetment - Plaquemines Shoreline

4.5.3. Combination of Sand and Coastal Structures Technique

The combination technique uses in situ and borrow material to construct the Alternatives as described Section 4.3. The use of coastal structures described in Section 4.4.4 is implemented as part of the combination technique. Areas containing revetments would not include the beach berm portion of the design and maintenance would pertain to the rocks only. All other areas would be maintained, using sand to restore beaches and dunes and rocks to repair damages to breakwaters and groins.

The Caminada-Moreau Headland and Plaquemines shoreline have not been considered for combinations of sand and structural techniques based on the low deposition rates shown by List *et al.* (1994). It appears that erosion in these areas occurs both in the nearshore and offshore regions with no accumulation of sediment. Construction of breakwaters or groins would severely erode downdrift shorelines. Therefore, these areas are not included in the sand and structure techniques, but will be evaluated for the sand only and revetment options.

The combination technique has the advantage of potentially reducing maintenance costs while creating a natural beach/dune/marsh environment. Table 12 lists the coastal structures used in the combination technique. Detailed sections of the proposed breakwaters and groins are shown in Figures 30 and 31, respectively. Figures 32 and 33 show the coastal structure layout for the sand and structure technique for the Isles Dernieres. Figure 34 illustrates the sand and structure technique for the Timbalier Islands. The revetments used in this technique are the same as used in the revetment only option. Appendix C and D contain the preliminary design procedure used in designing the breakwaters and terminal groins.

Table 12. Description and Location of Coastal Structures in the Sand and Structures Technique

Location	Alternative 1	Alternative 2
Isles Dernieres	27 Breakwaters at Whiskey Pass 1 Terminal Groin at Whiskey Island Expand Rock Revetment at Wine Island	Total of 42 Breakwaters 1 Terminal Groin at Raccoon Island
Timbalier Islands	Revetment at Raccoon Pass 30 Breakwaters at Timbalier Island Terminal Groin on Timbalier Island	Same as Alternative 1
Caminada-Moreau Headland	N/A	N/A
Plaquemines Shoreline	N/A	N/A

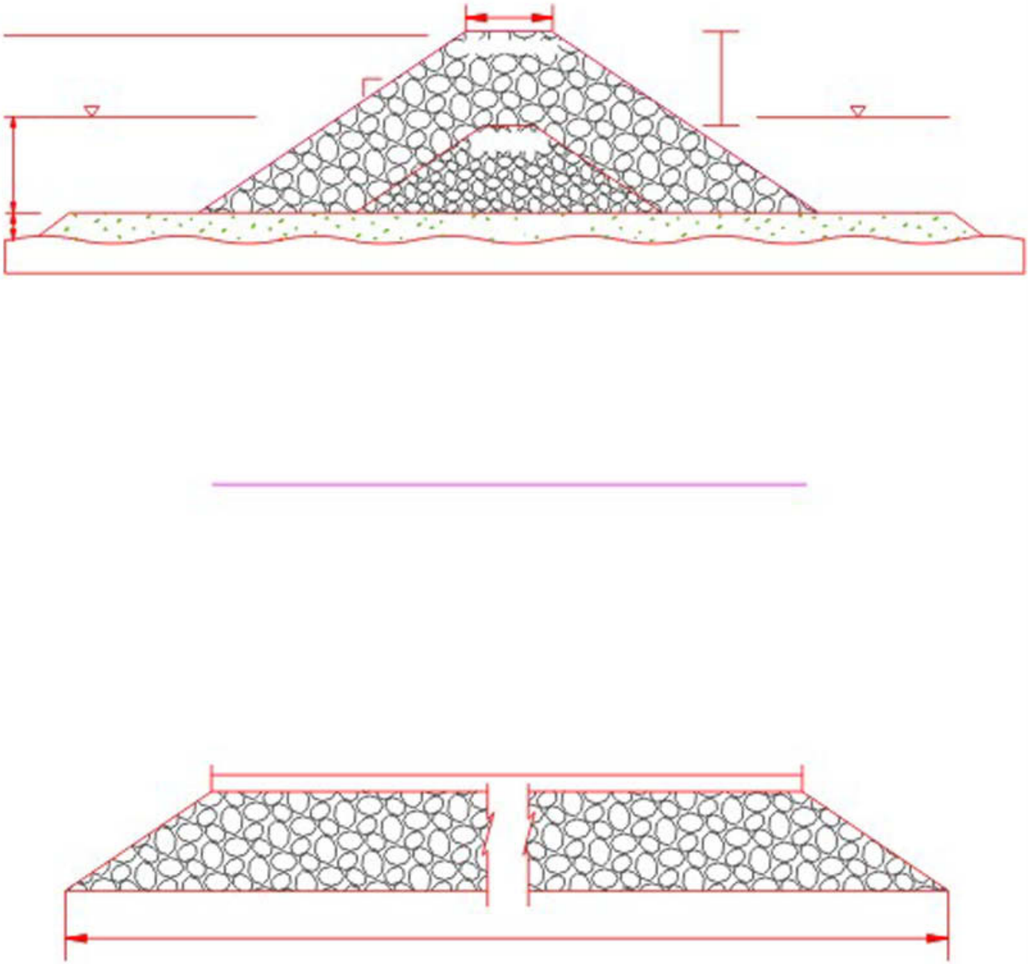
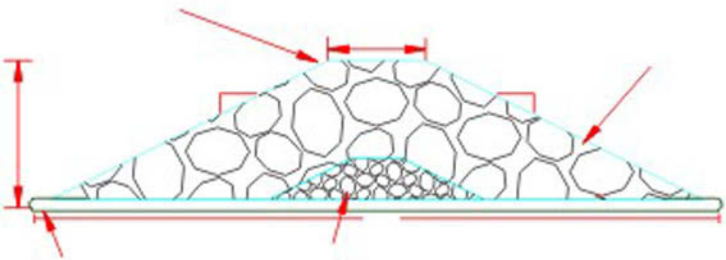


Figure 30. Typical Section/Profile - Segmented Offshore Breakwater



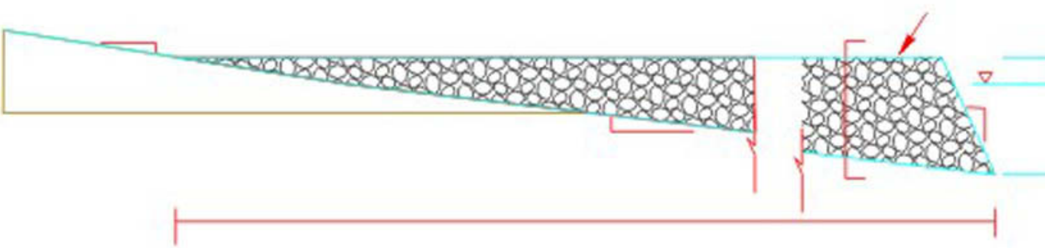


Figure 31. Typical Groin Section/Profile

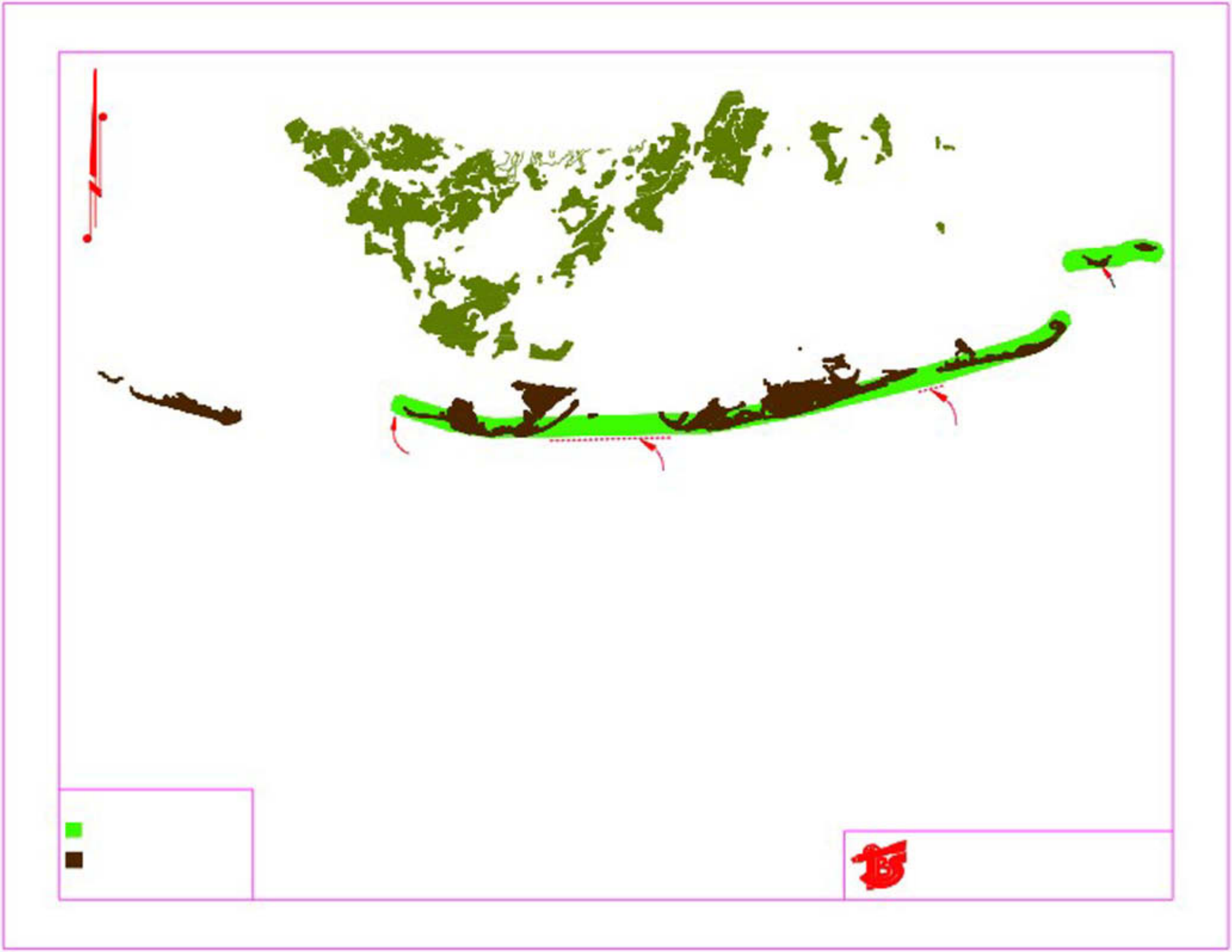


Figure 32.Isles Dernieres Sand and Structure Technique: Alternative 1

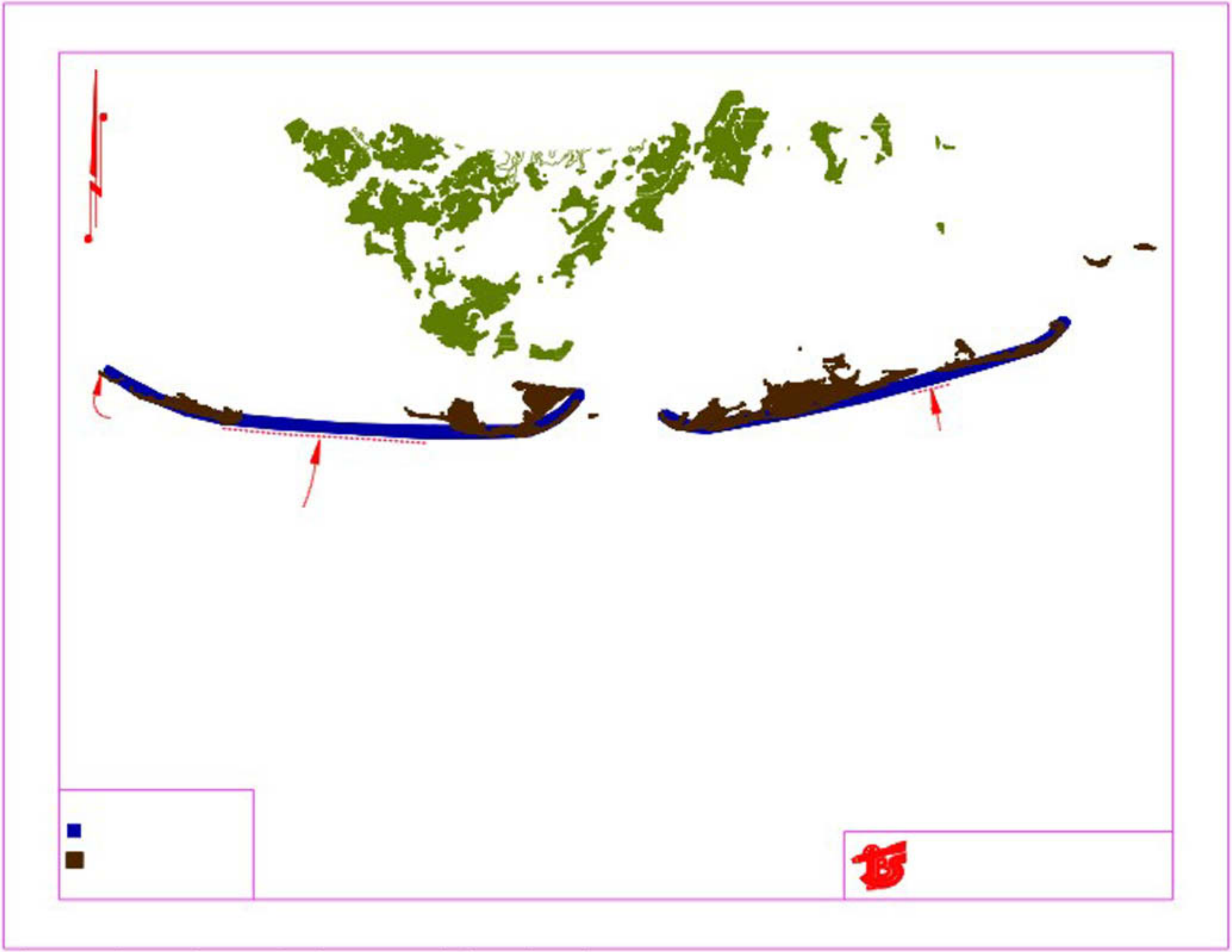


Figure 33.Isles Dernieres Sand and Structure Technique: Alternative 2

Figure 34.Timbalier Islands Sand and Structure Technique: Alternative 1

5.0 PRELIMINARY COST ESTIMATES

The preliminary project costs are presented as initial project cost, annual maintenance and repair costs, and average annual costs. Cost spreadsheets are presented in Appendices E-H, which are divided into the four sub-areas. Sections 5.1-5.3 describe the results of the preliminary cost estimates.

5.1. Initial Costs

The initial cost of the sand only and sand/structure projects assumes a two year construction time, with the first maintenance interval occurring at year five. Items included in the initial cost are: mobilization/demobilization, structural, back retention dikes, sandfill, engineering, vegetation, and contingencies. The revetment project assumes a five year construction period and includes the same cost items, except neither initial fill, nor maintenance beach fill are included. Initial construction times may vary and should be accounted for in the final engineering design.

Mobilization and demobilization costs are presented as a lump sum, to be used by the contractor to move equipment to the project site and remove it after completion. Structural costs include armor stones, underlayer and bed layer stones, filter cloth, and toe excavation used to construct revetment, groins, and breakwaters. Back retention dikes are separated from sandfill due to the increased cost of construction of levees used to contain fill material on the backside of the islands.

Sandfill includes several items such as: dune, beach fill, advanced beach fill, marsh platform, and confined sand platforms over open water. Dunes serve a dual role. Initially, they are front containment dikes. Then they are shaped to the proper elevation and planted, after dredging is completed, to form the protective dune system. Beach fill is unconfined fill along the foreshore placed as a buffer between the gulf and the dunes. Advanced fill is sacrificial beach placed seaward of the design beach fill to offset predicted losses between renourishment intervals. The marsh platform is the widest portion of the island, which is initially retained by the dunes and back containment dikes. Confined sand platforms consist of areas that are currently breaches or inlets (open water) overlaid with sand to conform to the design template.

Structural costs include armor stone, underlayer stone and/or bed layer material, geotextile fabric, and toe excavation where necessary. All rock is assumed to have a unit weight of 165 lb/ft^3 and costs $35/ton, based on previous project costs at Raccoon Island and Wine Island.

Engineering costs are estimated at 20% of the initial construction cost and 25% of maintenance project cost thereafter. These costs include basic services such as surveying, geotechnical investigations, engineering design, right-of-way acquisitions, permits, preparation of plans and specifications, and construction administration and inspection.

Project contingencies costs are 25% of the estimated construction cost and are set aside to cover unexpected conditions or uncertainties during the project design and construction phase. Table 13 shows the initial project cost for each engineering technique.

table 13xxx

5.1.1. Sand Only

The initial cost for the sand only techniques at the Isles Dernieres range from $133-$141 million for Alternative 1, compared to $104-$120 million for Alternative 2, based on return period designs of 5, 10, and 15 years as shown in Table 13. At the Timbalier Islands, the initial cost of the sand only option for the three design periods is $167-$174 million for Alternative 1 and $95-$109 for Alternative 2. The Plaquemines sand-only technique had an initial cost ranging from $317-$330 million for Alternative 1 and $211-$223 million for Alternative 2 for the three design periods. The Caminada-Moreau Headland had three design templates listed for Alternatives 1 and 2. The sand only technique in this sub-area ranges from $111-$116 million for the initial cost for return period designs of 5, 10, and 15 years. The wave absorbers, which are only considered in Alternative 1, have an initial cost of $21 million (Isles Dernieres), $31 million (Timbalier Islands), and $24 million (Plaquemines).

The initial cost of the sand only options increases as the level of protection increases. Therefore, the initial cost of a project designed for a 5-year return period event is less than that of the 10- and 15-year return period project designs. Alternative 2 was less expensive than Alternative 1 in all cases.

5.1.2. Revetment

The rock revetment initial cost at the Isles Dernieres is $194 and $185 million for Alternatives 1 and 2, respectively. At the Timbalier Islands, the initial cost of the rock revetment technique is $212 and $156 million for Alternatives 1 and 2, respectively. The Plaquemines shoreline revetment has initial costs of $381 and $294 for Alternatives 1 and 2. The Caminada-Moreau Headland revetment has an initial cost of $98 million for Alternatives 1 and 2. The wave absorbers cost is the same as that quoted for the sand-only technique.

The revetment option has an initial cost that is twice that of the sand-only option. The increase is due to the initial expense of placing rocks along the gulf shoreline. The initial cost is high, but maintenance costs will be less than that for the sand-only option.

5.1.3. Sand and Structures

The combination of sand and structures applies only to the Isles Dernieres and Timbalier Island chains as explained in Section 4.4.4. The sand and structure technique at the Isles Dernieres, based on return period designs of 5, 10, and 15 years, ranges from $142-$154 million for Alternative 1 and $115-$131 million for Alternative 2. The combination technique at the Timbalier Islands has initial project costs ranging from $167-$174 million for Alternative 1 and $95-$109 million for Alternative 2. The initial cost of the wave absorbers is the same quoted for the sand-only and revetment techniques.

The initial cost to construct the sand and structures technique is slightly higher than the sand only option due to the inclusion of breakwaters, groins, and revetments at specific locations. There is a reduction in project costs due to savings in areas that will not include a beach fill, such as Wine Island and East Timbalier Island due to their revetment stabilization. Anticipated savings will accrue in operation and maintenance costs.

5.2. Maintenance Costs

Maintenance costs include that associated with construction, engineering, and contingencies. Construction maintenance costs include periodic beach fill, dune repair, and/or structural repair. For the engineering analysis, a 30-year maintenance program was evaluated. Thirty years, as required in the Barrier Shoreline Feasibility Study, is a practical engineering project life to use in measuring and comparing construction and maintenance costs. Maintenance intervals will be every five years and will include advance beach fills to offset losses between maintenance cycles. Therefore, at year 30 the design template would be intact.

Beach fill estimates are based on sediment budgets over the last 50+ years. These sediment budgets were derived using the net erosion/accretion rates estimated for each sub-area found in List *et al.* (1994). An average volumetric rate per length of shoreline was determined and used to quantify future maintenance needs. This rate includes major and minor storm events, as well as daily erosive and accretional processes. The beach nourishment cycle occurs at five-year intervals and includes an advanced fill to compensate for losses within the five-year intervals. The sediment budget rates used for each sub-area are listed in Table 8.

It is noted that future volumetric loss rates will change and that this method for quantifying maintenance needs is, at best, a conservative estimate. Future erosion rates are expected to decrease due to the addition of sand and improved retention capability directly attributable to the alternatives. However, an extreme event, such as a 100 year return period event, has a 1% probability of occurring in any single year. Such an event exceeds the duration of the data set used to develop the sediment budget and may create catastrophic damage beyond the maintenance expectations of the alternatives. A monitoring program for the Louisiana barrier shoreline will provide the only practical data for future maintenance needs.

Dune maintenance costs are based on the total replacement cost of the dunes at return period intervals corresponding to the 50% probability of exceedance (e.g., 5, 10, or 15 years). Structural maintenance is a function of the estimated damages to armor stones as a function of the design wave height versus the return period wave height.

Annual maintenance costs were computed over the project life of 30 years. The results are shown in Table 14.

xxxinsert table 14

5.2.1. Sand Only

The sand-only annual maintenance cost for the Isles Dernieres varies, depending on the return period deign of 5, 10, or 15 years from \$5.5-\$5.6 million for Alternative 1 and \$5.3-\$5.9 million for Alternative 2. At the Timbalier Islands, the sand-only annual maintenance cost is \$9.8-\$10.0 million for Alternative 1 and \$8.7-\$8.9 million for Alternative 2, depending on the return period design. The Caminada-Moreau Headland has three design levels, which range from \$73.9-\$74.1 million annually for sand only maintenance cost. The Plaquemines shoreline has a sand-only maintenance cost ranging from \$40.2-\$40.5 million for Alternative 1 and \$37.2-\$37.4 million for Alternative 2 for the return period designs. The wave absorbers, as part of Alternative 1, have an added annual maintenance cost of \$291,000 (Isle Dernieres), \$437,000 (Timbalier Islands), and \$328,000 (Plaquemines).

The trend in annual maintenance cost is a slight increase from the 5- to the 10-year return period designs. The annual maintenance cost for the 15-year return period design falls below both the 5- and 10-year design levels. This is due to the savings resulting from building a larger dune height initially, and assuming dune maintenance only once during the project life.

5.2.2. Revetment

The revetment techniques annual maintenance cost is substantially lower than the sand-only cost. At the Isles Dernieres, the annual maintenance cost for the revetment options is \$358,000 for Alternative 1 and \$412,000 for Alternative 2. The Timbalier Islands revetment option has an annual maintenance cost of \$394,000 for Alternative 1 and \$353,000 for Alternative 2. The Caminada-Moreau Headland revetment option has an annual maintenance cost of \$419,000. At the Plaquemines shoreline, the annual revetment maintenance cost is \$1,140,000 for Alternative 1 and \$1,071,000 for Alternative 2. The wave absorbers have the same annual cost as those in the sand only option.

5.2.3. Sand and Structures

The rock revetments require considerably less money to maintain than does the sand-only option. This savings is primarily due to the deletion of a beach nourishment program, which raises the project cost due to the historically large volumetric losses of sand.

Combinations of sand and structural alternatives require less maintenance than sand-only, but are more expensive than the revetment option. At the Isles Dernieres, the sand and structures alternatives have an annual maintenance cost ranging from \$1.9-\$2.2 million for Alternative 1 and \$1.9-\$2.1 million for Alternative 2, depending on the return period design. At the Timbalier Islands, the sand and structure options have an annual maintenance cost ranging from \$2.5-\$3.2 million for Alternative 1 and \$1.7-\$2.0 million for Alternative 2, for return period designs of 5, 10, and 15 years. The wave absorbers have the same annual maintenance cost mentioned previously.

The sand and structure technique results in a steady decrease in the annual maintenance cost as the design level increases from 5 to 15 years. This is due to the combined benefits of designing higher dunes and requiring less beach maintenance in the future as a result of the coastal structures.

Actual maintenance changes for the island chains is not easily quantifiable due to the lack of a sediment source and the large spatial expanse of the projects. For this analysis, a 75% reduction in sediment budget losses is assumed where breakwaters and groins would be constructed. Actual shoreline morphology was not predicted, although it is acknowledged that downdrift effects and non-uniform deposition will occur. Shoreline change modeling can be used in the engineering design phase to better quantify beach fill needs at more localized scales of the island.

5.3. Average Annual Costs

The initial investment cost of each approach were converted to an annual cost figure using an interest rate of 8% and a project life of 30 years to compute interest and amortization. The annual maintenance cost was then added to the interest and amortization costs to develop the average annual cost of the engineering techniques. These average annual cost of each approach are shown in Table 15.

5.3.1. Sand Only

At the Isles Dernieres, as shown in Table 15, the average annual cost for the sand-only technique ranges from $17.4-$18.0 million for Alternative 1 and $15.1-$16.0 million for Alternative 2, depending on the return period design. The Timbalier Islands have a sand only option annual cost ranging from $24.8-$25.3 million for Alternative 1 and $17.3-$18.4 million for Alternative 2, for return period designs of 5, 10, and 15 years. The Caminada-Moreau Headland sand-only option has an average annual cost of $83.9-$84.2 million. At the Plaquemines shoreline, the sand-only option has an average annual cost of $68.6-$69.5 million for Alternative 1 and $56.1-$56.9 million for Alternative 2. The wave absorbers, as part of Alternative 1, have an annual cost of $2.2 million (Isles Dernieres), $3.2 million (Timbalier Islands), and $2.4 million (Plaquemines). Generally, the annual cost increases as the return period design increases, and Alternative 2 is less expensive in all scenarios compared to Alternative 1.

xxx insert table 15

5.3.2. Revetment

The rock revetment option at the Isles Dernieres has an average annual cost of \$17.6 million for Alternative 1 and \$16.9 million for Alternative 2. At the Timbalier Islands, the rock revetment annual cost is \$19.3 million for Alternative 1 and \$14.2 million for Alternative 2. The Caminada-Moreau Headland annual revetment cost is \$9.1 million. The Plaquemines shoreline annual cost for revetments is \$35.0 million for Alternative 1 and \$27.2 million for Alternative 2. The wave absorbers have the same annual cost as stated previously.

The rock revetment has a higher annual cost than the sand only option at the Isles Dernieres and Timbalier Islands. Conversely, the revetment annual cost is less expensive than the sand-only option for the Caminada-Moreau Headland and the Plaquemines shoreline. This difference is due to the extensive sand losses in sub-areas 3 and 4. Although the shoreline erosion rates are high for the Isles Dernieres and Timbalier Islands, the 30-year cost to maintain these areas using dune and beach nourishment offsets the initial investment of stabilizing the shoreline using rocks.

5.3.3. Sand and Structures

Using the combination of sand and structures at the Isles Dernieres results in an annual cost of \$14.7-\$15.6 million for Alternative 1 and \$12.3-\$13.5 million for Alternative 2, for return periods of 5, 10, and 15 years as shown in Table 15. At the Timbalier Islands, the annual cost ranges from \$20.6-\$20.8 million for Alternative 1 and \$11.3-\$12.3 million for Alternative 2, depending on the return period design. The wave absorbers have the same annual cost as stated previously.

The average annual cost of the sand and structure technique increases as the return period design increases. The sand and structure technique has the lowest annual cost compared to the other two techniques at the Isles Dernieres and Timbalier Islands.

6.0 ENVIRONMENTAL IMPACTS

The environmental impacts associated with the alternatives offer many benefits and create minimal long-term negative impacts. Benefits attributable to these projects include flood protection, recreational and commercial fisheries, creation of vegetative wetlands, protection of interior marsh, protection to oil and gas facilities, and other economic and environmental benefits. These benefits are quantified in Step J - Assessment of Management Alternatives and will be compared in Step L in recommending the proposed barrier island plan.

Apart from the resource benefits, the engineering techniques provide direct benefits in sustaining the islands over the 30 year project life. Also, the techniques have drawbacks, either in constructability, initial or maintenance costs, or downdrift effects to adjacent shorelines. These short- and long-term effects will be discussed in Sections 6.1 and 6.2.

6.1. Short-term impacts

Short term-impacts associated with the construction of the project pertain to the dredging of sand and the placement of sand and/or rocks. Cutterhead dredging is the probable method to be used for transporting sand. This will increase the concentration of suspended sediments in the water column. Settling basins will be used in the confined fill areas to retain sediment and reduce sediment discharge.

Compaction of sediment is a likely short-term effect when placing dredge material. Sand accumulates tightly as a result of the slurry placement technique used by the dredge. Wave and tidal action will loosen sand over the long-term.

Increases in turbidity can cause changes or reduction to some fish species and can be detrimental to light sensitive species of plants and fish. However, destruction of habitat is the primary detriment to nearshore fish living near the placement site. Placement of sand will smother benthic infauna (those organisms living within the sediments), but it should recover once construction ceases.

Placement of sand on the island could disrupt the nesting season for various species of birds due to movement of large volumes of water and construction operations associated with dredging. This can be avoided by dredging during non-nesting seasons and phasing projects so as to provide an alternative nesting area. Dredge disposal benefits the birds by providing small fish and other organisms to the birds through the discharge of the effluent.

Placement of sand in the nearshore causes increases in turbidity while the beach equilibrates to a natural slope. Finer materials are removed from the profile and are transported offshore. This impacts will have minimal impact on the environment.

As for the borrow sites, the act of dredging disrupts nearshore environments. The cutterhead, pipelines, anchors, and support equipment directly or indirectly disrupt the borrow area. This increases turbidity and directly destroys immobile fauna and flora. A large void would exist at the borrow site. Since these sites are primarily tidal shoals, it is expected to reshoal using material from the bays and updrift erosion of the barrier islands. This may have some negative impacts to the downdrift shorelines as updrift material is deposited back in the shoals. Also, a site specific analysis of the effects of dredging a particular tidal shoal should accompany more detailed engineering to ensure that potential negative impacts are minimized. Borrow areas should be wide and shallow so that poor water quality does not accumulate. Reasonable flushing in these areas is ecologically important.

Placement of sand directly on the island also destroys existing vegetation. This is a short-term impact, as the islands will be replanted at the completion of the fill placement, thus increasing the acreage of vegetated wetland.

6.2. Long-Term Impacts

There are many positive benefits described in Step J - Assessment of Management Alternatives that quantify the systemic impacts of restoring the barrier islands to Alternatives 1 and 2. The long-term impacts described in this section pertain to any long-term impacts associated with the direct movement and placement of sand on the islands.

Modified shorelines will take years to develop smooth curves consistent with the offshore bathymetry. Initial sand fills will spread throughout the nearshore, both laterally and offshore. Thus, the initial construction of the project will be a wide beach, but within the first year, waves will reshape the profile and transport much of the material creating shallower water depths offshore of the island. Erosion and deposition of material in new areas can be expected as waves reshape the sand added to the nearshore and react to the coastal structures.

The short-term impacts to beach profile are expected to occur at five-year intervals due to the maintenance of the beaches. Though not of the magnitude of the initial projects, millions of yards of sand must be periodically dredged and placed on the islands to renourish the beach profile. Thus, increases in turbidity and displacement of biologically dependent species in the nearshore must be expected. Proposed construction and habitat alteration for any of the alternatives and engineering techniques will not prevent migratory organisms that utilize barrier island habitats from completing their life cycle. Many species require the habitats (beach, dune, marsh platform) that will be constructed under these alternatives to complete their life cycles. Construction of the alternatives will have a direct, positive impact on these habitats.

Many eroding shorelines do not provide enough surface area for nesting of sea turtles. Although there has been not documented turtle nesting in the study area, restoring the beaches could provide proper nesting habitat. In addition, much more habitat is available to birds nesting and residing on the islands. Tidal cuts in the marsh platform will supply important nursery habitat to many aquatic species including shrimp, menhaden, drum, and other commercial and ecologically significant species.

As a rule, beach renourishment is the preferred approach to restoration of barrier islands. In some situations, however, coastal structures are necessary. Coastal structures are immobile features used to stabilize a shoreline and prevent shoreline change relative to the structure position. The barrier islands are migrating mobile features that constantly change to adapt to wave and tidal conditions, sea-level rise, and storms. Except for Grand Isle, the Phase 1 Study Area barrier islands are migrating and eroding. The employment of coastal structures on these ever-changing land masses naturally results in modifications that can be beneficial. Critical areas of erosion, for example, are expected following inlet closures, where the beach and dune system may be built similar to adjacent shorelines, but the bathymetry is different and may focus wave energy on that particular area. In these areas, coastal structures in the form of detached breakwaters may serve to stabilize the beach and shelter the island from larger waves. No coastal structure adds sediment to a system, but structures can be used to prohibit material from traveling in the system. In areas with a long, continuous shoreline, breakwaters may be a valid alternative to slow transport and may create or extend a beach. However, when numerous inlets and discontinuities in the island exist, detached breakwaters may add to the problem.

Because tidal currents will increase in areas where the inlet has been reduced (Alternative 1 - Little Pass), the final design of the projects may warrant armoring the ends of the islands until the passes deepen. Construction of breakwaters and/or revetments alter the ecology of beaches. To what extent this change would produce different communities of organisms is not well documented. It is documented, however, that hard structures (revetments, groins, wave absorbers, breakwaters) provide hard-bottom habitat near the islands and marsh edges. This hard water bottom habitat, of limited acreage in coastal Louisiana, may be considered a long-term positive impact to some organisms.

7.0. CONCLUSIONS

Alternative 1

Alternative 1 is the largest proposed barrier island option. The islands are built to a width of 1,970 feet, with optional dune heights ranging from +7.0 to +12.3 ft (msl). All recently formed breaches in the islands are closed and major inlets remain open. Alternative 1 includes an interior set of wave absorbers that serve as breakwaters to shelter saline marsh shorelines in Caillou Bay, Terrebonne Bay, Timbalier Bay, and Barataria Bay.

The initial project cost for Alternative 1 ranges from $716-$980 million for the Phase 1 Study Area. The annual maintenance cost for Alternative 1 ranges from $3.4-$131 million. Alternative 1 creates and restores 15,688 acres of wetlands on the barrier islands (24.5 mi^2) and provides a protective gulf shoreline extending 78.3 miles. The initial project cost includes the initial investment for designing and constructing the project. Average annual costs include interest and amortization of the original investment and provide operation and maintenance funding to preserve the 15,688 acres to the original design template for 30 years.

For the Isles Dernieres, the combination of sand and structures with a 5-year return period dune design has the lowest average annual cost at $14.7 million. At the Timbalier Islands, the combination of sand and structures with a 5-year return period dune design has the lowest average annual cost at $20.6 million. The revetment option has the lowest average annual cost at $9.1 million for the Caminada Moreau Headland. The revetment option has the lowest average annual cost of $37.4 million along the Plaquemines shoreline.

Alternative 2

Alternative 2 has a design width of 1,230 ft with optional dune heights ranging from +7.0 to +12.3 ft (msl). All island breaches and inlets created after 1988 are closed. Alternative 2 is confined to the barrier islands and does not contain any interior barriers.

The initial project cost for Alternative 2 ranges from $508-$751 million for the Phase 1 Study Area. The average annual maintenance cost for Alternative 2 ranges from $2.2-$102 million. Alternative 2 creates and restores 9,905 acres of wetlands on the barrier islands (15.5 mi^2) and provides a protective gulf shoreline extending 76.6 miles. The initial project cost includes the initial investment for designing and constructing the project. Average annual costs include interest and amortization of the original investment and provide operation and maintenance funding to preserve the 9,905 acres to the original design template for 30 years.

For the Isles Dernieres, the combination of sand and structures with a 5-year return period dune design has the lowest average annual cost at $12.3 million. At the Timbalier Islands, the combination of sand and structures with a 5-year return period dune design has the lowest average annual cost at $11.3 million. The revetment option has the lowest average annual cost at $9.1 million for the Caminada Moreau Headland. The revetment option has the lowest average annual cost of $27.2 million along the Plaquemines shoreline.

8.0. REFERENCES

American Society of Civil Engineers. 1994. *Coastal Groins and Nearshore Breakwaters*. Technical Engineering and Design Guides as Adapted from the U.S. Army Corps of Engineers, No. 6. ASCE Press. New York, New York. 85pp.

Adams, R. D., Banas, R. J., Baumann, R. H., Blackmon, J. H., and W.G. McIntire. 1978. *Shoreline Erosion In Coastal Louisiana: Inventory And Assessment*. Louisiana Department of Natural Resources, Baton Rouge. 103 p.

Boyd, R. and S. Penland. 1981. Washover of deltaic barriers on the Louisiana coast. *Transactions of the Gulf Coast Association of Geological Societies*, 31:243-248.

Bruun, P. 1954. *Coast Erosion and the Development of Beach Profiles*. US. Army Corps of Engineers. Journal Memorandum No. 44 Beach Erosion Control Board. Washington, D.C.

Byrnes, M.R. and C.G. Groat. 1991. *Characterization of the Development Potential of Ship Shoal Sand For Beach Replenishment of the Isles Dernieres*. Prepared by the Louisiana Geological Survey for the U.S. Minerals Management Service. Baton Rouge, Louisiana.

Dean, R.G. 1977. *Equilibrium Beach Profiles: U.S. Atlantic and Gulf Coasts*. Ocean Engineering Technical Report No. 12, Department of Civil Engineering. University of Delaware, Newark, D.E.

Dean, R.G. and R.A. Dalrymple. 1984. *Water Wave Mechanics for Engineers and Scientists*. Advanced Series on Ocean Engineering - Volume 2. World Scientific Publishing Co. Singapore. 353 p.

Dean, R.G. 1991. Equilibrium Beach Profiles: Characteristics and Applications. *Journal of Coastal Research* (7), 53-84.

Dean, R.G. and C. Yoo. 1993. Predictability of Beach Nourishment Performance. *Beach Nourishment Engineering and Management Considerations*, eds. D.K. Stauble and N.C. Kraus. American Society of Civil Engineers, 86-102.

Fisher, J.J. and E.J. Simpson. 1979. Washover and tidal sedimentation rate as environmental factors in development of a transgressive barrier shoreline: In S.P. Leatherman (ed.), *Barrier Islands*: Academic Press, p. 65-80.

Gravens, M.B. and J.D. Rosati. 1994. *Numerical Model Study of Breakwaters at Grand Isle, Louisiana*. Misc. Paper CERC-94-16. U.S. Army Corps of Engineers Waterways Experiment Station. Vicksburg Mississippi.

Hallermier, R.J. 1981. *Seaward Limit of Significant Sand Transport by Waves: An Annual Zonation for Seasonal Profiles*. Coastal Engineering Technical Aid No. 81-2, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Hoffman, J.S., Keyes, D., and J.G. Titus. 1983. *Projecting Future Sea Level Rise: Methodology, Estimates to the Year 2010, and Research Needs*. U.S. Environmental Protection Agency. Washington, D.C. 121 p.

Howard, P. C. 1982. *Quatre Bayou Pass, Louisiana: Analysis of currents, sediment, and history*. MS Thesis, Department of Geology, Louisiana State University, p. 110.

Kraus N.C. and S. Harikai. 1983. Numerical Model of Shoreline Change at Oarai Beach. *Coastal Engineering* 7(1): 1-28.

List, J., B.E. Jaffe, A.J. Sallenger, Jr., S.J. Williams, R.A. McBride, and S.P. Penland. 1994. *Louisiana Barrier Island Erosion Study - Atlas of seafloor changes from 1878 to 1989*: Miscellaneous Investigations Series I-2150-B, Scales 1:250,000 and 1:100,000, US Geological Survey, p. 82.

Marmer, H. A. 1954. *Tides and sea level in the Gulf of Mexico, in Gulf of Mexico, its origin, waters and marine life*. U. S. Fish and Wildlife Service Bulletin 55, p. 101-118.

McBride, R.A., M.R. Byrnes, and M.W. Hiland. 1995. Geomorphic response-type model for barrier coastlines - a regional perspective, in J. List and J.H.J. Terwindt, eds., *Marine Geology*, (126):143-159.

McCowan, J. 1894. On the Highest Wave of Permanent Type. *Philosophical Magazine Journal of Science* (38).

Myers, H.B. and A.R. Theis. 1956. Beach Erosion Control: Grand Isle, Louisiana. *Shore and Beach* (24):19-23.

National Research Council (NRC). 1995. *Beach Nourishment and Protection*. National Academy Press. Washington D.C. 334 p.

Ramsey, K. E., S. Penland and H. H. Roberts. 1991. Implications of accelerated sea-level rise on Louisiana coastal environments. *Coastal Sediments '91*. ASCE proceedings specialty conference/WR Div., Seattle, WA. June 25-27, 1991. p. 1207-1222.

Ritchie, W., Westphal, K.A., McBride, R.A., and Penland, S. 1989. *Coastal sand dunes of Louisiana--Isles Dernieres*. Coastal Geology Technical Report No. 5, Louisiana Geological Survey, Baton Rouge, LA. 60 pp.

Ritchie, W., Westphal, K.A., McBride, R.A., and Penland, S. 1990. *Coastal sand dunes of Louisiana--The Plaquemines Shoreline*. Coastal Geology Technical Report No. 6, Louisiana Geological Survey, Baton Rouge, LA. 90 pp.

Ritchie, W., Westphal, K.A., McBride, R.A., and Penland, S. 1995. *Coastal sand dunes of Louisiana--The Bayou Lafourche Barrier Shoreline*. Coastal Geology Technical Report No. 9, Louisiana Geological Survey, Baton Rouge, LA. 200 pp.

Schwartz, R.K. 1975. *Nature and Genesis of Storm Washover Deposits*. U. S. Army Corps of Engineers, Coastal Engineering Research Center: Technical memorandum 61. 69 p.

Stauble, D.K., Garcia, A.W., and N.C. Kraus. 1993. *Beach Nourishment Project Response and Design Evaluation: Ocean City, Maryland*. Technical Report CERC-93-13. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Suhayda, J.N. 1991. *Environmental Data and Conceptual Design for the Protection of Oil Production Facilities at East Timbalier Island.* Prepared for Greenhill Petroleum Corporation by Paragon Engineering Services.

Suter, J.R., Penland, S., and Ramsey, K.E. 1991. *Nearshore sand resources of the Mississippi River delta plain: Marsh Island to Sandy Point*. Coastal Geology Technical Report No. 8. Baton Rouge, LA: Louisiana Geological Survey. 130 pp.

Titus, J. G. 1988. *Greenhouse Effect, Sea Level Rise, and Coastal Wetlands*. U.S. Environmental Protection Agency. Washington, D.C., p. 192.

Traverse Group. 1988. *Preliminary Coastal Engineering Report: Isles Dernieres Barrier Island Stabilization Project*. Report to Plaisance/Smith Engineers. p. 153.

United States Army Corps of Engineers. 1971. *National Shoreline Study - Regional Inventory Report - Lower Mississippi Region Louisiana*. New Orleans District, New Orleans, La. 57 p.

U.S. Army Corps of Engineers. 1972. *Grand Isle and Vicinity Louisiana Review Report: Beach Erosion And Hurricane Protection*. New Orleans District, New Orleans, La. 69 p.

U.S. Army Corps of Engineers. 1979. *Grand Isle and Vicinity Louisiana General Design Memorandum: Beach Erosion And Hurricane Protection*. New Orleans District, New Orleans, La. 103 p.

U.S. Army Corps of Engineers. 1984. *Shore Protection Manual Volumes 1 and 2*. Waterways Experiment Station. Vicksburg, Mississippi.

U.S. Army Corps of Engineers. 1988. *Louisiana Coastal Area, Louisiana Shore and Barrier Island Erosion Grande Terre Islands, Louisiana Restoration Feasibility Study*. New Orleans District, New Orleans, La. 50 p.

U.S. Army Corps of Engineers 1989. *Water Levels and Wave Heights for Coastal Engineering Design*. E.M. 1110-2-1414. Washington, D.C. 87 pp.

U.S. Army Corps of Engineers 1995. *Design of Beach Fills*. E.M. 1110-2-3301. Washington, D.C. 87 pp.

van Beek, J.L. and K.J. Meyer-Arendt. 1982. *Louisiana's Eroding Coastline: Recommendations for Protection*. Prepared for Louisiana Department of Natural Resources, Baton Rouge, Louisiana. 49 pp.

van Beek, J.L. and K. Debusschere 1994. *Evaluation of Restoration Approaches for East Timbalier Island, Louisiana*. 32 pp.

Williams, S.J., S. Penland and A.H. Sallenger, Jr. (Eds.) 1992. *Atlas of Shoreline Changes in Louisiana from 1853-1989*. U.S. Geol. Survey, Misc. Invest. Series I-2150-A. 103 pp.

Woodward-Clyde Consultants. 1991. *Feasibility of Using Pipelines and Dredged Sediments to Restore Wetlands in Terrebonne Parish*. Terrebonne Parish Consolidated Government and the Environmental Protection Agency- Region 6. 35 pp.

Zetler, B. and D. Hansen. 1970. Tides in the Gulf of Mexico. *Bulletin of Maine Science*, (20) No.1, p. 57-69.

9.0. APPENDICES

Appendix A: Wave Absorber Design

Appendix B: Rubble Mound Revetment Design

Appendix C: Segmented Offshore Breakwater Design Appendix D: Terminal Groin Design

Appendix E: Preliminary Cost Estimate Spreadsheets -Isles Dernieres

Appendix F: Preliminary Cost Estimate Spreadsheets - Timbalier Islands

Appendix G: Preliminary Cost Estimate Spreadsheets - Caminada-Moreau Headland

Appendix H: Preliminary Cost Estimate Spreadsheets - Plaquemines Shoreline

Appendix A: Wave Absorber Design

WAVE ABSORBER DESIGN

Design Wave:

From Step G results, H_s , in the areas of the wave absorber, ranges from 0.4 - 0.6 m (1.3 - 2.0 ft.)

Significant wave height $\Rightarrow H_s = 2.0$ ft $\quad H_{1/10} = 1.27\ H_s = 1.27(2) =$ **2.54 ft**
(Recommended Design Guides from USACE, 1994)

$H_{1/10}$ is recommended for flexible rubble mound structures.

Significant wave period T = 5.0 sec.

Armor Stone:

W_A = weight of an individual armor unit (lbs.)

γ_a = unit weight of armor units $\left(\frac{165 lb}{ft^3}\right)$

K_d = Stability coefficient assumptions:

1) assuming a breaking wave to be conservative due to increased overtopping.
2) assume smooth rounded stone (2 layers) with random placement.

$\propto$ = angle of structure slope from horizontal

S_a = specific gravity of armor units $\left(S_a = \frac{g_a}{y_w} = \frac{165}{64} = 2.6\right)$

H = 2.54 ft

k_d = 2.4 (non-breaking wave; Quarry stone - smooth rounded

$\cot\alpha = 1.5$

$$W = \frac{g_a H^3}{k_d (S_a - 1)^3 \cot a} = \frac{\left(165 \frac{lb}{ft^3}\right)(2.54\, ft)^3}{2.4(2.6-1)^3 1.5}$$

W = 183 lb Þ use 200 lb

minimum Crest Width = $b = 3k_{\Delta}\left(\frac{W}{g_a}\right)^{\frac{1}{3}} = 3(1)\left(\frac{200lb}{165\frac{lb}{ft^3}}\right)^{\frac{1}{3}} = 3.2\,ft.$

use 5.0 ft.

k_{Δ} = layer thickness coefficient = 1.0 (see SPM)

Water depth = -4.0 ft (msl)   Storm surge = 2.0 ft   Water level = 6.0 ft

Breakwater Length = 300 ft
Breakwater Gap Width = 150 ft
Placement in 4 ft Water Depth

Breakwater Crest Elevation = water depth + tidal amplitude + wave runup
= 6 ft + 0.75 ft + 4.0 ft = 10.75 ft

Wave runup = 3.985 ≈ **4.0 ft**

Wave Absorbers Project Length:

1) Isle Dernieres

Caillou Bay = 42,750 feet = 95 breakwaters

Terrebonne Bay = 27,900 feet = 62 breakwaters

2) Timbalier Islands

Terrebonne Bay = 18,900 feet = 42 breakwaters

Timbalier Bay = 87,300 feet = 194 breakwaters

3) None in the Caminada - Moreau Headland Area

4) Plaquemines

Barataria Bay = 76,650 feet = 177 breakwaters

Exposure Ratio = ratio of gap width to the sum of the breakwater length and gap width. This is the fraction of shoreline directly exposed to waves and is equal to the fraction of incident wave energy reaching the shoreline. (ASCE, 1994)

$$\frac{150}{300+150} = \frac{1}{3} = 0.33 \Rightarrow \text{ 33\% of the shoreline is exposed to direct wave energy.}$$

The small exposure ratio provides maximum protection to the marsh shoreline while allowing exchange of water and sediments with the bays and marsh. Accretion on the sheltered side of the breakwaters is dependent on the sediment size and composition and their ability to settle and accumulate under adjusted wave conditions.

Materials and Placement Costs (per ft.)

$N_R = k_\Delta nA(1\text{-}P/100)(\gamma_r/W)^{2/3} = (1)(2)(0.63)(165/200)^{2/3} = 1.11$ stones per square foot.

Armor Stone: 8.1 tons/ft
Bed Layer: 0.84 tons/ft
Filter Cloth: 41.0 ft^2/ft

Per breakwater (300 ft at bottom; 286 ft at mid height)

Item	Quantity	Unit Cost, $	Total Cost, $
Armor Stone	2,323 tons	35/cy	81,305
Bed Layer	241	35/cy	8,435
Filter Cloth	11,726	0.50/ft	5,863
			$95,603/breakwater

Maintenance:

An 8 year return period event has an approximate storm surge of +3 ft. (msl) at the barrier islands. This may differ at fringing marsh edges due to water level setups, but the surge elevation at the marsh will be assumed at +3 ft. (msl) for the analysis.

The average highest 10% of all waves in the protected bay is approximately 2.54 ft at the marsh shoreline. For the 8 year event, the highest 1% will be used as an approximation due to actual wave measurements need to be taken for adequate design and maintenance costs.

$H_{1/100} = 1.67\ H_s = 3.33$ ft.

$$\frac{H}{H_p} = \frac{3.33}{2.54} = 1.31 \Rightarrow 30\%$$

Therefore, maintenance costs to the wave absorbers is $2,439 each per year.

Appendix B: Rubble Mound Revetment Design

Rubble Mound Revetment Design - Isles Dernieres/Timbalier Islands

Wave Conditions:

Wave Height	Wave Period	Water Depth
H_{mo} = 1.0 m (3.3 ft)	T_p = 5 sec.	Depth = 33 m (125 ft)

Irregular Wave Transformation:

$H_{1/3}$ = 3.3 ft. $H_{1/10}$ = 4.4 ft.

$H_{1/3}$ = average of the highest 33% of all wave heights
$H_{1/10}$ = average of the highest 10% of all wave heights

For a flexible rubble mound structure use:

$H_{1/10}$ = 4.4 ft T = 6 sec. Crest Angle = 0º depth = 33 m (108.24 ft)

Design Water Level:

a) Relative Sea Level Rise in 30 years	=	1.0 ft. (msl)
Tide Range	=	0.7 ft. (msl)
		+1.7 ft. (msl)

b) Storm Surge:

5 year design level uses the 5 year return period storm surge. This storm surge has a 20% probability of occurring in any given year. It also has a 67% probability of being exceeded in 5 years.

8 year design level uses the 8 year return period storm surge. This storm surge has a 12.5% probability of occurring in any given year. It also has ˜ 50% probability of being exceeded in 5 years.

15 year design level uses the 15 year return period storm surge. This storm surge has a 6.6% probability of occurring in any given year. It also has a 50% probability of being exceeded in 10 years.

22 year design level uses the 22 year return period storm surge. This storm surge has a 4.5 % probability of occurring in any given year. It also has 50% probability of being exceeded in 15 years.

30 year design level uses the 30 year return period storm surge. This storm surge has a 3.3% probability of occurring in any given year. It also has 64% probability of being exceeded in 30 years.

Surge Elevation, ft

(Return Period)	Percent Probability of Occurrence 5 year	10 year	15 year	30 year
1.0 (5 yr)	67%	89%	96%	100%
2.9 (8 yr)	49%	74%	87%	98%
6.0 (15 yr)	29%	50%	64%	87%
7.9 (22 yr)	21%	37%	50%	75%
9.0 (30 yr)	16%	29%	40%	64%

Wave runup

Breaking Wave Criteria: slope = 1:100 T = 6 sec H = 4.4 ft

H_b = Maximum breaking wave height for designated return frequency plus relative sea level rise and tidal range.

$H_{b(5\ yr)}$ = 2.4 ft. < 4.4 ft.	Use 2.4 ft.
$H_{b(8\ yr)}$ = 3.9 ft. < 4.4 ft.	Use 3.9 ft.
$H_{b(15\ yr)}$ = 6.5 ft. > 4.6 ft.	Use 4.6 ft.
$H_{b(22\ yr)}$ = 7.9 ft. > 4.5 ft.	Use 4.5 ft.
$H_{b(30\ yr)}$ = 8.8 ft. > 4.4 ft.	Use 4.4 ft.

(Used Table 2-2 EM 1110-2-1614 to find H_b).

(Using ACES Structural Design: Rubble Mound Revetment Design).

Wave runup:	4.3 ft	(5 yr)
	6.5 ft.	(8 yr)
	8.8 ft.	(15 yr)
	8.8 ft.	(22 yr)
	8.7 ft.	(30 yr)

Crest Elevation

Design Level	Water Level, ft. (msl)	Runup, ft.	Crest Elevation, ft. (msl)
5 yr	2.7	4.3	7.0
8 yr	4.6	6.5	11.1
15 yr	7.7	8.8	16.5
22 yr	9.6	8.8	18.4
30 yr	10.7	8.7	19.4

Elevations for design levels with 15, 22, and 30 year return periods significantly exceed island height constraints of alternatives 1 and 2. The design elevations also appear to be cost prohibitive.

The 5 year return period design elevation is 7.0 ft. This is less than the 8.2 ft. revetment elevation reported at East Timbalier. To avoid the same fate as East Timbalier Island, we should eliminate the 5 year design level and use a higher crest elevation.

Therefore, the 8 year design level was pursued, which has a 50% probability of the design height exceeding conditions with a 5 year return period.

Estimated Toe Scour Depths for Revetment Options

The minimum scour depth for a quarrystone revetment is 2.5 ft. (EM 1110-2-1614)

The toe scour depth below the natural bottom is assumed to be equal to the wave height (H_b = 3.9 ft.). The assumed scour depth is 5.0 ft. to allow a conservative estimate for increased scour due to probable increases in wave height due to erosion at the toe.

Armor Layer

a. Stone Size

W_{50} = average required individual armor unit weight (lb.)

γ_r = specific weight of the armor unit, (lb/ft^3) = 165

H = design wave height = 3.9 ft.

k_d = Stability coefficient = 2.2

γ_w = specific weight of saltwater, (lb/ft^3) = 64.0

$$W = W_{50} = \frac{\gamma_r H^3}{k_d\left(\frac{\gamma_r}{\gamma_w} - 1\right)^3 \cot\theta} = \frac{\left(165\frac{lb}{ft^3}\right)(3.9\,ft)^3}{2.2\left(\frac{165\frac{lb}{ft^3}}{64\frac{lb}{ft^3}} - 1\right)^3 2} = W_{50} = 566 \text{ lb.}$$

b) Layer thickness

Armor Layer thickness = $r = nK\Delta\left(\frac{W}{\gamma_w}\right)^{1/3}$

n = number of unit layers = 2

K_Δ = layer coefficient = 1.0

Percent Less than by Weight	Weight (lb.)	Dimension (ft.)
0 min	71	0.75
15	226	1.11
50	566	1.51
85	1110	1.89
100 max	2264	2.39

minimum layer thickness = $r_{min} = \max\left[2.0\left(\frac{W_{50\ min}}{\gamma_r}\right)^{1/3}; 1.25\left(\frac{W_{100\ min}}{\gamma_r}\right)^{1/3}; 1ft\right]$

$$r_{min} = 2\left(\frac{566lb}{165\frac{lb}{ft^3}}\right)^{1/3} = 3.02 ft.$$

$$r_{min} = 1.25\left[\frac{4(566)}{165}\right]^{1/3} = 2.99 ft.$$

r_{min} = 1 ft.

Use r_{min} = 3.02 ft.

Porosity = P = 0.37 for Graded Riprap

$N_R = k_\Delta nA(1\text{-}P/100)(\gamma_r/W)^{2/3} = (1)(2)(0.63)(165/566)^{2/3} = 0.554$ stones per square foot.

Toe protection

The toe protection stone weight equals that of the armor stone (566 lb) due to potential forces due to waves acting near the toe protection on a daily basis.

Assume a low scour potential and give the toe protection a thickness layer of r_{min} = 3.02 ft. built on a 1:2 slope. The toe scour depth will be 5 ft. below the mudline.

Filter Layers

a) Riprap and armor stone underlayer:

$$\frac{d_{15}\text{armor}}{d_{85}\text{filter}} < 4 \Rightarrow d_{85}\text{filter} = \frac{1.11\text{ft.}}{4} = 0.28\text{ft}$$

Percent Less that by Weight	Weight(lb.)	Dimension(ft)
0 (min)	0.19	0.10
15	0.31	0.12
50	1.05	0.19
85	3.54	0.28
100 (min)	5.96	0.33

Assume underlayer thickness = 3(0.19 ft.) = 0.57 ft; approximately 0.6 ft.

b) Filter fabric selection:

Assume sand content on beach is greater than 50%.

The equivalent opening size (EOS) can be calculated using:

$$\frac{EOS_{sieve}}{d_{85}\text{soil}} \leq 1$$

Using soil boring data from the Traverse Report (1988),

d_{85} = 0.10 mm.

$EOS_{sieve} \leq$ 0.1 mm.

Site Preparation

a) Dune Construction (300 ft. wide)

Front Dike	4.6 yd^3/ft
Sand Fill	123.3 yd^3/ft
Back Dike	10.6 yd^3/ft

b) Back Barrier (+3 msl)

Back Dike	24.5 yd^3/ft
Sand Fill	96.4 yd^3/ft
Total	259.4 yd^3/ft

Material Costs for Armor Stone Revetment Alternative per 1,000 ft. of shoreline

Item	Quantity	Unit Cost, $	Total Cost, $
Armor Stone	5,740 tons	35/ton	200,900
Underlayer	1,351 tons	35/ton	47,285
Filter Cloth	53,400 ft^2	0.50/ft^2	26,700
Toe Excavation	2,600 yd^3	2.00/ yd^3	5,200
			$280,085

= $280/ft of shoreline

Maintenance

The revetment is designed to withstand an 8 year storm event with less than 13% damage to the armor layer in 8 years using Table 7-9 from the (USACE 1984). Table 7-9 (USACE 1984) is based on the volume of armor units displaced for a given wave height. Primary damage occurs at the still-water level (design water level), with decreasing damage as depth increases. Damages greater than 30% warrant total failure of a revetment's armor stone.

Assuming a maintenance interval of five years, a 15 year return period event has a 29% probability of occurring in 5 years. The probability of the event is too infrequent for the calculating the maintenance cycle. Therefore, the 8 year return period event with a 49% probability of occurrence is chosen for calculating maintenance frequency at five year intervals. This corresponds to 8.1 % of the cost of the armor stone every five years, or $3.25/ft/yr.

Appendix C: Segmented Offshore Breakwater Design

NEARSHORE SEGMENTED BREAKWATER (Coupe Abel)

Structures are placed in -6 ft. of water (msl).

y_s = distance from the shoreline to the salient
y = distance from the breakwater to the shoreline
ℓ = breakwater length
y_b = distance from breakwater to the breaking waves

Assume nearshore slope is 1:100. Breaking wave depth is approximately -4.2 ft. (msl). Placement of breakwaters is in -5 ft. (msl) of water, therefore y_b = (100)(6-4.2 ft.) = 180 ft.
y = (100)(5 ft.) = 500 ft.

$\frac{\ell}{y}$ is recommended to be <1.0 to form a salient, but not a tombolo. (SPM 1984). Assuming $\frac{\ell}{y}$ = 0.6 (ℓ = 300 ft.; y = 500 ft.). Suh and Dalyrymple recommend

Relationship 1: $\frac{\ell}{y} < 2\frac{b}{\ell} \Rightarrow$ assuming a gap width (b) of 300 ft.; $\frac{\ell}{y} = 0.6 < \left[\frac{2(300)}{(300)}\right] = 2$

Relationship 2: $\frac{\ell}{y} < 1.5$

$\therefore$ A well developed salient is predicted using Ahrens and Cox (1990) relationship.

Multiple breakwaters:

$$y_s = 14.8y\frac{b\,y}{\ell^2}\ \exp\left[-2.83\sqrt{\left(\frac{by}{\ell^2}\right)}\right] = 319\text{ ft.}$$

This is likely an overprediction of the salient that would actually occur. This relationship does not account for regression in salient widths downdrift. However, the design dimensions, with an exposure ratio of 0.5, will likely produce salients of varying magnitudes along critical points of the island.

Design Waves and Water Levels:

	Wave height	Wave Period	Water Depth
Deepwater	H_{mo}=1.0 m (3.3 ft)	T_p=5 sec.	Depth = 38 m (125 ft)

Irregular Wave Transformation

$H_{1/3}$ = 3.3 ft. $H_{1/10}$ = 4.4 ft.

Design Water Level:

Water depth =	-5.0 ft. (msl)
Relative sea level rise:	1.0 ft.
Tidal amplitude =	<u>0.7 ft.</u>
	6.7 ft.

Return Period	5 years	8 years	15 years
Storm Surge* (msl)	1.0 ft.	4.4 ft.	6.0 ft.
Water Depth	5.7 ft.	5.7 ft.	5.7 ft.
Total Water Depth (msl)	7.0 ft.	10.4 ft.	12.0 ft.

*includes tidal amplitude

Based on the typical groin design, significant waves break seaward of the structure.

Assume a crest elevation of 3.7 ft. above design water level; total structure height 10.4 ft.

Design wave of 8.1 ft. (8 year surge event)

H = 8.1 ft.

$\gamma_w = 64\dfrac{lb}{ft^3}$

$$W = \frac{H^3 g_s}{k_D\left(\dfrac{g_s}{g_w} - 1\right)^3 \cot a} = 3{,}823 lb$$

$\gamma_s = 165\dfrac{lb}{ft^3}$

$\cot\alpha = 2.0$

$k_D = 2.8$ (rough angular quarrystore)

<u>Crest Width:</u>

$$b = 3k_\Delta\left[\frac{W_a}{g_a}\right]^{\frac{1}{3}} = 3(1)\left(\frac{3{,}823 lb}{165\dfrac{lb^3}{ft}}\right)^{\frac{1}{3}} = 8.6 ft.$$

Primary armor thickness = $r = nk_{\Delta}\left[\frac{W_a}{g_a}\right]^{\frac{1}{3}} = 2(1)\left(\frac{3{,}823lb}{165\frac{lb}{ft^3}}\right)^{\frac{1}{3}} = 5.7ft.$

First Underlayer: W = $\left(\frac{1}{10}\right)(3{,}823) = 382lb$

$$r = (2)(1)\left[\frac{382lb}{165\frac{lb}{ft^3}}\right]^{\frac{1}{3}} = 2.6ft.$$

<u>Bedding Layer</u>:

A bedding layer of crushed limestone (minimum of 1 ft. thick) is placed in conjunction with filter cloth to limit settlement and prevent scour.

NEARSHORE BREAKWATER (ISLES DERNIERES and TIMBALIER ISLAND)

Functional design is same as breakwater at Coupe Abel.

y = distance from the breakwater to the shoreline = 600 ft.
ℓ = breakwater length = 300 ft.
y_b = distance from breakwater to the breaking waves
b = gap width = 300 ft.

Assume water depth is -5.0 ft. (msl). Nearshore slope is 1:100.

Design Waves and Water Levels:

Deepwater:	Wave Height	Wave Period	Water Depth
	$H_{1/3}$ = 1.0 m (3.3 ft)	T_p = 5 sec.	Depth = 33m (125 ft)

Irregular Wave Transformation:

$H_{1/3}$ = 3.3 ft $H_{1/10}$ = 4.4 ft

Design Water Level:

Water Depth =	-5 ft. (MSL)
Relative sea level rise =	1 ft.
Tidal Amplitude =	0.7 ft
	6.7 ft

Return Period	5 years	8 years	15 years
Storm Surge* (msl)	1.0 ft.	2.9 ft.	6.0 ft.
Water Depth	6.0 ft.	6.0 ft.	6.0 ft.
Total Water Depth (msl)	7.0 ft.	8.9 ft. (Use 10 ft)	12.0 ft.

*Includes tidal amplitude

Crest elevation is 1.5 ft. above design water level; total structure height is 10.4 ft. 1.1 ft. is added to the crest elevation to prevent overtopping of smaller event wave conditions.

Based on the groin calculations, significant waves will break seaward of the breakwaters.

Design for a breaking wave of 8.1 ft., use design for Coupe Abel.

W = 3,823 lb.
W/10 = 382 lbs.

crest width = 8.6 ft.

min. armor layer thickness = 5.7 ft.

$N_R = k_\Delta nA(1\text{-}P/100)(\gamma_r/W)^{2/3} = (1)(2)(0.63)(165/3823)^{2/3} = 0.155$ stones per square foot.

Materials and Placement Costs:

Armor Stone: 10.6 tons/ft
Underlayer Stone: 3.2 tons/ft
Bed Layer: 1.6 cy/ft
Filter cloth: 55 ft^2/ft

Item	Quantity	Unit Cost, $	Total Cost, $
Armor Stone	2,957 ton	35/ton	103,495
Underlayer	893 ton	35/ton	31,255
Bedlayer	446 cy	78/cy	34,788
Filter Cloth	15,345 cy	0.50/ft^2	7,673
			$177,211/breakwater

Maintenance:

The typical breakwater is designed to withstand less than 5% damage in an 8 year event. Assuming a 10 year maintenance interval, a 15 year event has a 50% chance of occurring, resulting in a design water depth of 12.0 ft. and a design breaking wave of 9.6.

$H/H_d = 9.6/8.1 = 1.19$. Using Table 7-9 (SPM 1984), assume 12.5% damage in 10 years to the armor stone. Maintenance of the breakwaters is therefore $1,294 per breakwater annually.

Appendix D: Terminal Groin Design

TERMINAL GROIN DESIGN

Functional Design:

a) Objective: The objective of the terminal groins proposed is to retain sand traveling in the dominant longshore current. Since the groins will be placed in areas where beach nourishment ends and where expected downdrift erosion is minimal, the structures ace as terminal groins.

b) Groin Length: The groins are not intended to be sand tight nor will they prevent sand bypassing under certain conditions. Review of the Seafloor Change Atlas (List *et al.* 1994) shows that most sand accumulation near Timbalier Island has occurred in water depths less than 2.0 m (6.6 ft). Similarly, Hallermeier (1981) estimated that longshore transport occurs in water depths up to 1.6 times the wave breaking depth of the significant wave height.

Breaking wave depth: $\frac{3.3 ft}{(.78)} = 4.2 ft$

Limit of longshore transport = (1.6)(4.2 ft) = 6.7 ft ⇒ -6.7 ft (msl)

Groin length = nearshore slope x (6.7 ft + relative sea level and tidal range) + (beach berm slope x beach berm height)

Assume 75% trapping efficiency based on USACE (1984) criteria for high groins in less than 10 ft. of water and greater than 3.9 ft. (MLW).

c) Groin Height: The groins will be built above MHW and account for relative sea level rise

Nearshore groin height = relative sea level rise + tidal range

Foreshore groin height = relative sea level rise + tidal range + average berm height

Wave Conditions:

Wave height	Wave Period	Water Depth
H_{mo} = 1.0 m (3.3 ft)	T_p = 5 sec.	Depth = 33 m (108 ft)

Irregular Wave Transformation: $H_{1/3}$ = 3.3 ft $H_{1/10}$ = 4.4 ft.

Design Water Level:

a) Relative Sea Level rise in 30 yrs. = 1.0 ft
Tide Range = 0.7 ft (msl)
1.7 ft (msl)

b) Storm Surge:

Height (ft)	Return period
+1.0	5 yr
+2.9	8 yr
+6.0	15 yr
+7.9	22 yr
+9.0	30 yr

Groin Height (above msl): nearshore = 1.7 ft (msl)

Groin Length: [100 x (6.7 ft + 2 ft)] + (75 x 2 ft) = 990 ft

Design Wave:

Breaking wave computation (assume $d_B = 1.28\ H_B$)

m = 1:100	H_0 =10.8 ft (5 yr)		H_o = 12.1 ft (10 yr)		H_o = 13.1 ft (15 yr)	
Wave Period(sec)	H_b(ft)	d_B(ft)	H_b(ft)	d_B(ft)	H_b(ft)	d_B(ft)
4.0	9.0	12.5	9.8	13.8	10.4	14.8
6.0	11.1	14.1	12.1	15.5	12.8	16.6
8.0	13.3	16.4	14.4	17.9	15.3	19.1

Total Water Depth

Return Period	Structure	Surge	Water Depth at Toe (msl), ft*	Total Depth, ft
5	Depth at toe	1.0	6.7	7.7
	Depth at crest	1.0	1.7	2.7
15	Depth at toe	6.0	6.7	12.0
	Depth at crest	6.0	1.7	7.7
22	Depth at toe	7.9	6.7	14.6
	Depth at crest	7.9	1.7	9.6

*Includes relative sea level rise and MHW

Use d_S = 7.7 ft

From Figure 7-4 (SPM 1984)

T (sec)	d_s/gT^2	H_b/d_s	H_b (ft)
4	0.016	0.82	6.3
6	0.007	0.85	6.5
8	0.004	0.86	6.6
10	0.002	0.87	6.7

Wave periods greater than or equal to 8 seconds occur only 4.9% of the time, therefore, the design wave equals 6.5 ft.

Stone Design:

Armor Stone: $$W = \frac{w_r H^3}{k_d\left(S_r - 1\right)^3 \cot q}$$

w_r = 1.65 lb/ft^3

H = 6.5 ft.

cot θ = 2

k_d = 1.6 (two random layers of rough angular quarry stone at the structure head) (SPM, 1984)

S_r = 2.60

W = 3,457 lb

Range of quarry stone is 2,593 lb to 4,321 lb

Crest Thickness:

$$r = nk_D(W)^{1/3}$$

$$r = 2(1)\left(\frac{3{,}958\,lb}{165\frac{lb}{ft^3}}\right) = 5.5\,ft$$

Underlayer stone = W/10 = 346 lb

Range for W/10 = 242 to 450 lb

Bedding will consist of a sand layer and crushed limestone. Filter cloth (EOS = 0.1) will be used.

Water Depth	Underlayer Stone Quantity	Armor
-6.7	29.8 ft^3/ft	169.4 ft^3/ft
-5.7	16.1 ft^3/ft	144.8 ft^3/ft
-4.7	6.4 ft^3/ft	120.2 ft^3/ft
-3.8	0	0
	137.4 cy	2,239 cy

$N_R = k_\Delta nA(1\text{-}P/100)(\gamma_r/W)^{2/3} = (1)(2)(0.63)(165/3{,}457)^{2/3} = 0.166$ stones per square foot.

Cost Estimates:

Item	Quantity	Cost, $	Total Cost, $
Armor Stone	3,135 tons	35/ton	$109,725
Underlayer Stone	192 tons	35/ton	$ 6,720
Bed Layer	220 cy	78/cy	$ 17,160
Filter Cloth	22,000 ft^2	0.50/ft^2	$ 11,000
			$144,605/groin

Maintenance:

The typical groin is designed to withstand less than 5% damage in a 15 year event. A 22 year event has a 50% chance of occurring in 15 years. This results in a design wave of 8.2 ft at 9.6 ft water depth at the crest

$H/H_d = 8.2/6.5 = 1.26$. Using Table 7-9 (USACE 1984), assume 17.5% damage is 15 years to the armor stone. Maintenance is $1,280 per year for each groin.

Appendix E: Preliminary Cost Estimate Spreadsheets - Isles Dernieres

Isles Dernieres: Alternative 1 - 5 year Return Period Design

Project Acreage	3,855 acres
Project Island(s) Length	16.8 miles
Island Restoration and Periodic Beach and Dune Nourishment	
Dune height	7 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	2,168,402	cu. yd.	4.00	8,673,610
Sandfill				
Dune	1,434,820	cu. yd.	4.00	5,739,282
Beach Fill	3,347,999	cu. yd.	1.30	4,352,399
Advanced Fill1	4,584,794	cu. yd.	1.30	5,960,232
Back Barrier Berm	22,503,070	cu. yd.	1.30	29,253,991
Confined Sand Platform Over Open Water	12,556,800	cu. yd.	1.30	16,323,840
Subtotal	44,427,483	cu. yd.		71,303,353
Vegetation				
Aerial Planting	3,123	acre	150.00	468,383
Hand Planting	116	acre	3,388.00	391,822
Subtotal				860,205
Engineering (20%) 2				14,432,712
Contingencies (25%)				18,040,889
Total First Cost				104,637,159

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				104,637,159
Amortization factor				0.088827
Interest and Amortization				9,294,605
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	9,628,067	cu. yd.	1.30	12,516,487
Subtotal				13,516,487
Engineering (25%) 2				3,379,122
Contingencies (25%)				3,379,122
Total cost of one periodic nourishment				20,274,730
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			36,891,585
Total present worths				36,891,585
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				3,276,969
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	508,550	cu. yd.	4.00	2,034,202
Engineering (25%) 2				508,550
Contingencies (25%)				508,550
Subtotal				3,051,302
Present worths of maintenance brought back at years 5, 10, 15, 20, 25	1.819584502			5,552,103
Total present worths				5,552,103
Amortization factor				0.088827
Annual cost of structure and dune maintenance				493,177
Summary of Annual Costs				
Interest and Amortization				9,294,605
Initial and Periodic Beach Nourishment				3,276,969
Structure and Dune Maintenance				493,177
Total Annual Costs				13,064,750

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Isles Dernieres: Alternative 1 - 10 year Return Period Design

Total Acreage	3,855 acres
Total Island(s) Length	16.8 miles
Island Restoration and Periodic Beach and Dune Nourishment	
Dune height	10.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	2,168,402	cu. yd.	4.00	8,673,610
Sandfill				
Dune	2,739,324	cu. yd.	4.00	10,957,296
Beach Fill	3,345,347	cu. yd.	1.30	4,348,951
Advanced Fill1	2,977,139	cu. yd.	1.30	3,870,280
Back Barrier Berm	22,039,106	cu. yd.	1.30	28,650,838
Confined Sand Platform Over Open Water	12,556,800	cu. yd.	1.30	16,323,840
Subtotal	43,657,715	cu. yd.		73,824,814
Vegetation				
Aerial Planting	3,057	acre	150.00	458,552
Hand Planting	150	acre	3,388.00	509,369
Subtotal				967,921
Engineering (20%) 2				14,958,547
Contingencies (25%)				18,698,184
Total First Cost				108,449,466

Annual Costs

Interest and Amortization3				
First Cost				108,449,466
Amortization factor				0.088827
Interest and Amortization				9,633,241
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	9,628,067	cu. yd.	1.30	12,516,487
Subtotal				13,516,487
Engineering (25%) 2				3,379,122
Contingencies (25%)				3,379,122
Total cost of one periodic nourishment				20,274,730
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			36,891,585
Total present worths				36,891,585
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				3,276,969
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	1,499,411	cu. yd.	4.00	5,997,646
Engineering (25%) 2				1,499,411
Contingencies (25%)				1,499,411
Subtotal				8,996,468
Present worths of maintenance brought back at years 10, 20	0.677741695			6,097,282
Total present worths				6,097,282
Amortization factor				0.088827
Annual cost of structure and dune maintenance				541,603
Summary of Annual Costs				
Interest and Amortization				9,633,241
Initial and Periodic Beach Nourishment				3,276,969
Structure and Dune Maintenance				541,603
Total Annual Costs				13,451,813

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Isles Dernieres: Alternative 1 - 15 year Return Period Design

Total Acreage 3,855 acres
Total Island(s) Length 16.8 miles
Island Restoration and Periodic Beach and Dune Nourishment
Dune height 12.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	2,168,402	cu. yd.	4.00	8,673,610
Sandfill				
Dune	3,683,735	cu. yd.	4.00	14,734,940
Beach Fill	3,361,454	cu. yd.	1.30	4,369,890
Advanced Fill1	2,977,139	cu. yd.	1.30	3,870,280
Back Barrier Berm	21,743,992	cu. yd.	1.30	28,267,190
Confined Sand Platform Over Open Water	12,556,800	cu. yd.	1.30	16,323,840
Subtotal	44,323,120	cu. yd.		77,239,750
Vegetation				
Aerial Planting	3,018	acre	150.00	452,770
Hand Planting	170	acre	3,388.00	574,673
Subtotal				1,027,442
Engineering (20%) 2				15,653,438
Contingencies (25%)				19,566,798
Total First Cost				113,487,429

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				113,487,429
Amortization factor				0.088827
Interest and Amortization				10,080,748
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	9,628,067	cu. yd.	1.30	12,516,487
Subtotal				13,516,487
Engineering (25%) 2				3,379,122
Contingencies (25%)				3,379,122
Total cost of one periodic nourishment				20,274,730
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			36,891,585
Total present worths				36,891,585
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				3,276,969
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	2,274,350	cu. yd.	4.00	9,097,402
Engineering (25%) 2				2,274,350
Contingencies (25%)				2,274,350
Subtotal				13,646,102
Present worths of maintenance brought back at year 15	0.315241705			4,301,821
Total present worths				4,301,821
Amortization factor				0.088827
Annual cost of structure and dune maintenance				382,118
Summary of Annual Costs				
Interest and Amortization				10,080,748
Initial and Periodic Beach Nourishment				3,276,969
Structure and Dune Maintenance				382,118
Total Annual Costs				13,739,834

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Isles Dernieres: Alternative 1 - Revetment Option

Project Acreage	3,855 acres
Project Island(s) Length	16.8 miles
Revetment Option	
Dune height	+11.1 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Armor Stone	518,236	ton	35.00	18,138,257
Underlayer Stone	121,975	ton	35.00	4,269,126
Filter Cloth	4,821,219	sq. ft.	0.50	2,410,610
Toe Excavatrion	234,741	cu. yd.	2.00	469,482
Back Retention Dike	2,211,983	cu. yd.	4.00	8,847,930
Sandfill				
Dune	12,089,162	cu. yd.	4.00	48,356,646
Back Barrier Berm	24,162,975	cu. yd.	1.30	31,411,867
Confined Sand Platform Over Open Water	12,556,800	cu. yd.	1.30	16,323,840
Subtotal	48,808,936	cu. yd.		131,227,757
Vegetation				
Aerial Planting	3,188	acre	150.00	478,213
Hand Planting	667	acre	3,388.00	2,259,508
Subtotal				2,737,721
Engineering (20%) 2				26,793,096
Contingencies (25%)				33,491,369
Total First Cost				194,249,943

Annual Costs

Interest and Amortization2			
First Cost			194,249,943
Amortization factor			0.088827
Interest and Amortization			17,254,640
Periodic Structure and Dune Maintenance			
Structure and Dune Maintenance	2,357,973	LS	2,357,973
Engineering (20%) 1			471,595
Contingencies (25%)			589,493
Subtotal			3,419,061
Present worths of maintenance brought back at years 10, 15, 20, 25	1.139001305		3,894,315
Total present worths			3,894,315
Amortization factor			0.088827
Annual cost of structure and dune maintenance			345,920
Summary of Annual Costs			
Interest and Amortization			17,254,640
Structure and Dune Maintenance			345,920
Total Annual Costs			17,600,560

1 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

2 Amortization over 30-yr period at 8%.

** 60-month period of construction

Isles Dernieres: Alternative 1 - 5 year Return Period Design

Project Acreage 3,855 acres
Project Island(s) Length 16.8 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components
Dune height 7 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3134.6	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cy	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	80,136	ton	35.00	2,804,760
Underlayer Stone	24,268	ton	35.00	849,366
Bedlayer	12,042	cy	78.00	939,276
Filter Cloth	414,315	sq. ft.	0.50	207,158
Revetment:				
Armor Stone	69,707	ton	35.00	2,439,730
Underlayer Stone	16,407	ton	35.00	574,229
Filter Cloth	648,490	sq. ft.	0.50	324,245
Toe Excavation	31,574	cy	2.00	63,149
Back Retention Dike	2,168,402	cu. yd.	4.00	8,673,610
Sandfill				
Dune	1,434,820	cu. yd.	4.00	5,739,282
Beach Fill	2,604,135	cu. yd.	1.30	3,385,375
Advanced Fill[1]	3,939,526	cu. yd.	1.30	5,121,384
Back Barrier Berm	22,503,070	cu. yd.	1.30	29,253,991
Confined Sand Platform Over Open Water	12,556,800	cu. yd.	1.30	16,323,840
Subtotal	43,038,352	cu. yd.		77,843,978
Vegetation				
Aerial Planting	3,123	acre	150.00	468,383
Hand Planting	116	acre	3,388.00	391,822
Subtotal				860,205
Engineering (20%) [2]				15,740,836
Contingencies (25%)				19,676,046
Total First Cost				114,121,064

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization[3]				
First Cost				114,121,064
Amortization factor				0.088827
Interest and Amortization				10,137,032
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	1,855,222	cu. yd.	1.30	2,411,788
Subtotal				3,411,788
Engineering (20%) [2]				682,358
Contingencies (25%)				852,947
Total cost of one periodic nourishment				4,947,093
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			9,001,653
Total present worths				9,001,653
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				799,590
Periodic Structure and Dune Maintenance				
Structure Maintenance	597,783	LS		597,783
Dune Maintenance	436,977	cu. yd.	4.00	1,747,907
Engineering (20%) [2]				947,364
Contingencies (25%)				1,034,759
Subtotal				4,327,812
Present worths of maintenance brought back at years 5, 10, 15, 20, 25	1.819584502			7,874,820
Total present worths				7,874,820
Amortization factor				0.088827
Annual cost of structure and dune maintenance				699,497
Summary of Annual Costs				
Interest and Amortization				10,137,032
Initial and Periodic Beach Nourishment				799,590
Structure and Dune Maintenance				699,497
Total Annual Costs				11,636,118

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Isles Dernieres: Alternative 1 - 10 year Return Period Design

Project Acreage 3,855 acres
Project Island(s) Length 16.8 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components
Dune height 7 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3,135	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cy	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	80,136	ton	35.00	2,804,760
Underlayer Stone	24,268	ton	35.00	849,366
Bedlayer	12,042	cy	78.00	939,276
Filter Cloth	414,315	sq. ft.	0.50	207,158
Revetment:				
Armor Stone	69,707	ton	35.00	2,439,730
Underlayer Stone	16,407	ton	35.00	574,229
Filter Cloth	648,490	sq. ft.	0.50	324,245
Toe Excavation	31,574	cy	2.00	63,149
Back Retention Dike	2,168,402	cu. yd.	4.00	8,673,610
Sandfill				
Dune	2,739,324	cu. yd.	4.00	10,957,296
Beach Fill	2,602,071	cu. yd.	1.30	3,382,693
Advanced Fill1	3,939,526	cu. yd.	1.30	5,121,384
Back Barrier Berm	22,039,106	cu. yd.	1.30	28,650,838
Confined Sand Platform Over Open Water	12,556,800	cu. yd.	1.30	16,323,840
Subtotal	43,876,828	cu. yd.		82,456,156
Vegetation				
Aerial Planting	3,057	acre	150.00	458,552
Hand Planting	150	acre	3,388.00	509,369
Subtotal				967,921
Engineering (20%) 2				16,684,815
Contingencies (25%)				20,856,019
Total First Cost				120,964,912

Annual Costs

Interest and Amortization3				
First Cost				120,964,912
Amortization factor				0.088827
Interest and Amortization				10,744,950
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	1,855,222	cu. yd.	1.30	2,411,788
Subtotal				3,411,788
Engineering (25%) 2				852,947
Contingencies (25%)				852,947
Total cost of one periodic nourishment				5,117,682
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			9,312,055
Total present worths				9,312,055
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				827,162
Periodic Structure and Dune Maintenance				
Structure Maintenance	1,195,565	LS		1,195,565
Dune Maintenance	1,499,411	cu. yd.	4.00	5,997,646
Engineering (25%) 2				2,694,977
Contingencies (25%)				2,694,977
Subtotal				12,583,164
Present worths of maintenance brought back at years 10 and 20	0.677741695			8,528,135
Total present worths				8,528,135
Amortization factor				0.088827
Annual cost of structure and dune maintenance				757,529
Summary of Annual Costs				
Interest and Amortization				10,744,950
Initial and Periodic Beach Nourishment				827,162
Structure and Dune Maintenance				757,529
Total Annual Costs				12,329,641

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Isles Dernieres: Alternative 1 - 15 year Return Period Design

Project Acreage 3,855 acres
Project Island(s) Length 16.8 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components
Dune height 12.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3,135	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cy	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	80,136	ton	35.00	2,804,760
Underlayer Stone	24,268	ton	35.00	849,366
Bedlayer	12,042	cy	78.00	939,276
Filter Cloth	414,315	sq. ft.	0.50	207,158
Revetment:				
Armor Stone	69,707	ton	35.00	2,439,730
Underlayer Stone	16,407	ton	35.00	574,229
Filter Cloth	648,490	sq. ft.	0.50	324,245
Toe Excavation	31,574	cy	2.00	63,149
Back Retention Dike	2,168,402	cu. yd.	4.00	8,673,610
Sandfill				
Dune	3,683,735	cu. yd.	4.00	14,734,940
Beach Fill	2,614,600	cu. yd.	1.30	3,398,980
Advanced Fill1	3,939,526	cu. yd.	1.30	5,121,384
Back Barrier Berm	21,743,992	cu. yd.	1.30	28,267,190
Confined Sand Platform Over Open Water	12,556,800	cu. yd.	1.30	16,323,840
Subtotal	46,707,056	cu. yd.		85,866,439
Vegetation				
Aerial Planting	3,018	acre	150.00	452,770
Hand Planting	170	acre	3,388.00	574,673
Subtotal				1,027,442
Engineering (20%) 2				17,378,776
Contingencies (25%)				21,723,470
Total First Cost				125,996,128

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				125,996,128
Amortization factor				0.088827
Interest and Amortization				11,191,858
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	1,855,222	cu. yd.	1.30	2,411,788
Subtotal				3,411,788
Engineering (25%) 2				852,947
Contingencies (25%)				852,947
Total cost of one periodic nourishment				5,117,682
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			9,312,055
Total present worths				9,312,055
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				827,162
Periodic Structure and Dune Maintenance				
Structure Maintenance	1,793,348	LS		1,793,348
Dune Maintenance	2,274,350	cu. yd.	4.00	9,097,402
Engineering (25%) 2				4,067,698
Contingencies (25%)				4,067,698
Subtotal				19,026,146
Present worths of maintenance brought back at year 15	0.315241705			5,997,835
Total present worths				5,997,835
Amortization factor				0.088827
Annual cost of structure and dune maintenance				532,770
Summary of Annual Costs				
Interest and Amortization				11,191,858
Initial and Periodic Beach Nourishment				827,162
Structure and Dune Maintenance				532,770
Total Annual Costs				12,551,790

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Isles Dernieres: Alternative 1 - Wave Absorbers

Project Length	13.4 miles
Number of Breakwaters	157

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Armor Stone	364,648	ton	35.00	12,762,687
Bed Layer Stone	27,004	cu. yd.	78.00	2,106,312
Filter Cloth	1,840,982	sq. ft.	0.50	920,491
Subtotal				16,789,490
Engineering (20%) 1				3,357,898
Contingencies (25%)				4,197,373
Total First Cost				24,344,761

Annual Costs

Interest and Amortization2			
First Cost			24,344,761
Amortization factor			0.088827
Interest and Amortization			2,162,472
Periodic Structure Maintenance			
Structure Maintenance	1,914,403	LS	1,914,403
Engineering (20%) 1			382,881
Contingencies (25%)			478,601
Subtotal			2,775,884
Present worths of maintenance brought back at years 10, 15, 20, 25	1.139001305		3,161,736
Total present worths			3,161,736
Amortization factor			0.088827
Annual cost of structure maintenance			280,848
Summary of Annual Costs			
Interest and Amortization			2,162,472
Structure Maintenance			280,848
Total Annual Costs			2,443,320

1 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

2 Amortization over 30-yr period at 8%.

** 60-month period of construction

Isles Dernieres: Alternative 2 - 5 year Return Period Design

Total Acreage 2,866 acres
Total Island(s) Length 19.4 miles
Island Restoration and Periodic Beach and Dune Nourishment
Dune height 7 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	2,505,709	cu. yd.	4.00	10,022,838
Sandfill				
Dune	1,927,481	cu. yd.	4.00	7,709,926
Beach Fill	4,319,258	cu. yd.	1.30	5,615,036
Advanced Fill1	3,440,249	cu. yd.	1.30	4,472,324
Back Barrier Berm	16,363,825	cu. yd.	1.30	21,272,973
Confined Sand Platform Over Open Water	12,164,400	cu. yd.	1.30	15,813,720
Subtotal	40,720,924	cu. yd.		65,906,816
Vegetation				
Aerial Planting	1,992	acre	150.00	298,781
Hand Planting	140	acre	3,388.00	475,790
Subtotal				774,571
Engineering (20%) 2				13,336,277
Contingencies (25%)				16,670,347
Total First Cost				96,688,011

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				96,688,011
Amortization factor				0.088827
Interest and Amortization				8,588,506
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	10,595,968	cu. yd.	1.30	13,774,758
Subtotal				14,774,758
Engineering (20%) 2				2,954,952
Contingencies (25%)				3,693,690
Total cost of one periodic nourishment				21,423,399
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			38,981,685
Total present worths				38,981,685
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				3,462,626
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	587,658	cu. yd.	4.00	2,350,633
Engineering (20%) 2				470,127
Contingencies (25%)				587,658
Subtotal				3,408,418
Present worths of maintenance brought back at years 5, 10, 15, 20, 25	1.819584502			6,201,904
Total present worths				6,201,904
Amortization factor				0.088827
Annual cost of structure and dune maintenance				550,897
Summary of Annual Costs				
Interest and Amortization				8,588,506
Initial and Periodic Beach Nourishment				3,462,626
Structure and Dune Maintenance				550,897
Total Annual Costs				12,602,029

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Isles Dernieres: Alternative 2 - 10 year Return Period Design

Total Acreage 2,866 acres
Total Island(s) Length 19.4 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components
Dune height 10.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	2,505,709	cu. yd.	4.00	10,022,838
Sandfill				
Dune	3,701,151	cu. yd.	4.00	14,804,602
Beach Fill	4,335,898	cu. yd.	1.30	5,636,667
Advanced Fill1	3,440,249	cu. yd.	1.30	4,472,324
Back Barrier Berm	15,708,960	cu. yd.	1.30	20,421,649
Confined Sand Platform Over Open Water	12,164,400	cu. yd.	1.30	15,813,720
Subtotal	41,856,368	cu. yd.		72,171,800
Vegetation				
Aerial Planting	1,914	acre	150.00	287,173
Hand Planting	178	acre	3,388.00	602,020
Subtotal				889,194
Engineering (20%) 2				14,612,199
Contingencies (25%)				18,265,248
Total First Cost				105,938,441

Annual Costs

Item	Quantity	Unit	Unit Cost	Cost
Interest and Amortization3				
First Cost				105,938,441
Amortization factor				0.088827
Interest and Amortization				9,410,194
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	10,595,968	cu. yd.	1.30	13,774,758
Subtotal				14,774,758
Engineering (25%) 2				3,693,690
Contingencies (25%)				3,693,690
Total cost of one periodic nourishment				22,162,137
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			40,325,881
Total present worths				40,325,881
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				3,582,027
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	1,732,653	cu. yd.	4.00	6,930,613
Engineering (25%) 2				1,732,653
Contingencies (25%)				1,732,653
Subtotal				10,395,919
Present worths of maintenance brought back at years 10, 20	0.677741695			7,045,748
Total present worths				7,045,748
Amortization factor				0.088827
Annual cost of structure and dune maintenance				625,853
Summary of Annual Costs				
Interest and Amortization				9,410,194
Initial and Periodic Beach Nourishment				3,582,027
Structure and Dune Maintenance				625,853
Total Annual Costs				13,618,074

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Isles Dernieres: Alternative 2 - 15 year Return Period Design

Total Acreage	2,866 acres
Total Island(s) Length	19.4 miles
Island Restoration and Periodic Beach and Dune Nourishment	
Dune height	12.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	2,505,709	cu. yd.	4.00	10,022,838
Sandfill				
Dune	4,966,168	cu. yd.	4.00	19,864,672
Beach Fill	4,377,949	cu. yd.	1.30	5,691,334
Advanced Fill1	3,440,249	cu. yd.	1.30	4,472,324
Back Barrier Berm	15,315,367	cu. yd.	1.30	19,909,977
Confined Sand Platform Over Open Water	12,164,400	cu. yd.	1.30	15,813,720
Subtotal	40,264,133	cu. yd.		76,774,865
Vegetation				
Aerial Planting	1,869	acre	150.00	280,295
Hand Planting	201	acre	3,388.00	679,701
Subtotal				959,995
Engineering (20%) 2				15,546,972
Contingencies (25%)				19,433,715
Total First Cost				112,715,547

Annual Costs

Interest and Amortization3				
First Cost				112,715,547
Amortization factor				0.088827
Interest and Amortization				10,012,184
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	10,595,968	cu. yd.	1.30	13,774,758
Subtotal				14,774,758
Engineering (25%) 2				3,693,690
Contingencies (25%)				3,693,690
Total cost of one periodic nourishment				22,162,137
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			40,325,881
Total present worths				40,325,881
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				3,582,027
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	2,628,138	cu. yd.	4.00	10,512,553
Engineering (25%) 2				2,628,138
Contingencies (25%)				2,628,138
Subtotal				15,768,829
Present worths of maintenance brought back at year 15	0.315241705			828,499
Total present worths				828,499
Amortization factor				0.088827
Annual cost of structure and dune maintenance				73,593
Summary of Annual Costs				
Interest and Amortization				10,012,184
Initial and Periodic Beach Nourishment				3,582,027
Structure and Dune Maintenance				73,593
Total Annual Costs				13,667,804

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Isles Dernieres: Alternative 2 - Revetment Option

Project Acreage	2,866 acres
Project Island(s) Length	19.4 miles
Revetment Option	
Dune height	+11.1 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Armor Stone	597,144	ton	35.00	20,900,029
Underlayer Stone	140,547	ton	35.00	4,919,153
Filter Cloth	5,555,309	sq. ft.	0.50	2,777,654
Toe Excavatrion	270,483	cu. yd.	2.00	540,966
Back Retention Dike	3,823,176	cu. yd.	1.00	3,823,176
Sandfill				
Dune	13,929,885	cu. yd.	4.00	55,719,539
Back Barrier Berm	15,043,027	cu. yd.	1.30	19,555,935
Confined Sand Platform Over Open Water	12,164,400	cu. yd.	1.30	15,813,720
Subtotal	41,137,312	cu. yd.		125,050,173
Vegetation				
Aerial Planting	2,167	acre	150.00	325,004
Hand Planting	699	acre	3,388.00	2,369,242
Subtotal				2,694,246
Engineering (20%) 2				25,548,884
Contingencies (25%)				31,936,105
Total First Cost				185,229,408

Annual Costs

Item	Quantity	Unit	Cost ($)
Interest and Amortization2			
First Cost			185,229,408
Amortization factor			0.088827
Interest and Amortization			16,453,373
Periodic Structure and Dune Maintenance			
Structure and Dune Maintenance	2,717,004	LS	2,717,004
Engineering (20%) 1			543,401
Contingencies (25%)			679,251
Subtotal			3,939,655
Present worths of maintenance brought back at years 10, 15, 20, 25	1.139001305		4,487,273
Total present worths			4,487,273
Amortization factor			0.088827
Annual cost of structure and dune maintenance			398,591
Summary of Annual Costs			
Interest and Amortization			16,453,373
Structure and Dune Maintenance			398,591
Total Annual Costs			16,851,964

1 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

2 Amortization over 30-yr period at 8%.

** 60-month period of construction

Isles Dernieres: Alternative 2 - 5 year Return Period Design

Project Acreage 2,866 acres
Project Island(s) Length 19.4 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components
Dune height 7 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3,135	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cu. yd.	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	124,656	ton	35.00	4,362,960
Underlayer Stone	37,750	ton	35.00	1,321,236
Bedlayer	18,732	cu. yd.	78.00	1,461,096
Filter Cloth	644,490	sq. ft.	0.50	322,245
Back Retention Dike	2,505,709	cu. yd.	4.00	10,022,838
Sandfill				
Dune	1,927,481	cu. yd.	4.00	7,709,926
Beach Fill	4,319,258	cu. yd.	1.30	5,615,036
Advanced Fill1	3,440,249	cu. yd.	1.30	4,472,324
Back Barrier Berm	16,363,825	cu. yd.	1.30	21,272,973
Confined Sand Platform Over Open Water	12,164,400	cu. yd.	1.30	15,813,720
Subtotal	38,215,214	cu. yd.		73,518,937
Vegetation				
Aerial Planting	1,992	acre	150.00	298,781
Hand Planting	140	acre	3,388.00	475,790
Subtotal				774,571
Engineering (20%) 2				14,858,702
Contingencies (25%)				18,573,377
Total First Cost				107,725,587

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				107,725,587
Amortization factor				0.088827
Interest and Amortization				9,568,941
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	2,317,868	cu. yd.	1.30	3,013,228
Subtotal				4,013,228
Engineering (20%) 2				802,646
Contingencies (25%)				1,003,307
Total cost of one periodic nourishment				5,819,181
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			10,588,492
Total present worths				10,588,492
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				940,544
Periodic Structure and Dune Maintenance				
Structure Maintenance	432,952	LS		432,952
Dune Maintenance	587,658	cu. yd.	4.00	2,350,633
Engineering (20%) 2				903,078
Contingencies (25%)				1,020,610
Subtotal				4,707,273
Present worths of maintenance brought back at years 5, 10, 15, 20, 25	1.819584502			8,565,281
Total present worths				8,565,281
Amortization factor				0.088827
Annual cost of structure and dune maintenance				760,828
Summary of Annual Costs				
Interest and Amortization				9,568,941
Initial and Periodic Beach Nourishment				940,544
Structure and Dune Maintenance				760,828
Total Annual Costs				11,270,313

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Isles Dernieres: Alternative 2 - 10 year Return Period Design

Project Acreage	2,866 acres
Project Island(s) Length	19.4 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components	
Dune height	10.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3,135	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cu. yd.	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	124,656	ton	35.00	4,362,960
Underlayer Stone	37,750	ton	35.00	1,321,236
Bedlayer	18,732	cu. yd.	78.00	1,461,096
Filter Cloth	644,490	sq. ft.	0.50	322,245
Back Retention Dike	2,505,709	cu. yd.	4.00	10,022,838
Sandfill				
Dune	3,701,151	cu. yd.	4.00	14,804,602
Beach Fill	4,335,898	cu. yd.	1.30	5,636,667
Advanced Fill1	3,440,249	cu. yd.	1.30	4,472,324
Back Barrier Berm	15,708,960	cu. yd.	1.30	20,421,649
Confined Sand Platform Over Open Water	12,164,400	cu. yd.	1.30	15,813,720
Subtotal	39,350,658	cu. yd.		79,783,921
Vegetation				
Aerial Planting	1,914	acre	150.00	287,173
Hand Planting	178	acre	3,388.00	602,020
Subtotal				889,194
Engineering (20%) 2				16,134,623
Contingencies (25%)				20,168,279
Total First Cost				116,976,016

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				116,976,016
Amortization factor				0.088827
Interest and Amortization				10,390,629
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	2,317,868	cu. yd.	1.30	3,013,228
Subtotal				4,013,228
Engineering (25%) 2				1,003,307
Contingencies (25%)				1,003,307
Total cost of one periodic nourishment				6,019,843
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			10,953,612
Total present worths				10,953,612
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				972,977
Periodic Structure and Dune Maintenance				
Structure Maintenance	865,904	LS		865,904
Dune Maintenance	1,732,653	cu. yd.	4.00	6,930,613
Engineering (25%) 2				2,598,557
Contingencies (25%)				2,598,557
Subtotal				12,993,630
Present worths of maintenance brought back at years 10 and 20	0.677741695			8,806,325
Total present worths				8,806,325
Amortization factor				0.088827
Annual cost of structure and dune maintenance				782,239
Summary of Annual Costs				
Interest and Amortization				10,390,629
Initial and Periodic Beach Nourishment				972,977
Structure and Dune Maintenance				782,239
Total Annual Costs				12,145,844

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Isles Dernieres: Alternative 2 - 15 year Return Period Design

Project Acreage 2,866 acres
Project Island(s) Length 19.4 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components
Dune height 12.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3,135	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cu. yd.	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	124,656	ton	35.00	4,362,960
Underlayer Stone	37,750	ton	35.00	1,321,236
Bedlayer	18,732	cu. yd.	78.00	1,461,096
Filter Cloth	644,490	sq. ft.	0.50	322,245
Back Retention Dike	2,505,709	cu. yd.	4.00	10,022,838
Sandfill				
Dune	4,966,168	cu. yd.	4.00	19,864,672
Beach Fill	4,377,949	cu. yd.	1.30	5,691,334
Advanced Fill1	3,440,249	cu. yd.	1.30	4,472,324
Back Barrier Berm	15,315,367	cu. yd.	1.30	19,909,977
Confined Sand Platform Over Open Water	12,164,400	cu. yd.	1.30	15,813,720
Subtotal	40,264,133	cu. yd.		84,386,986
Vegetation				
Aerial Planting	1,869	acre	150.00	280,295
Hand Planting	201	acre	3,388.00	679,701
Subtotal				959,995
Engineering (20%) 2				17,069,396
Contingencies (25%)				21,336,745
Total First Cost				123,753,123

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				123,753,123
Amortization factor				0.088827
Interest and Amortization				10,992,619
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	2,317,868	cu. yd.	1.30	3,013,228
Subtotal				4,013,228
Engineering (25%) 2				1,003,307
Contingencies (25%)				1,003,307
Total cost of one periodic nourishment				6,019,843
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			10,953,612
Total present worths				10,953,612
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				972,977
Periodic Structure and Dune Maintenance				
Structure Maintenance	1,298,855	LS		1,298,855
Dune Maintenance	2,628,138	cu. yd.	4.00	10,512,553
Engineering (25%) 2				3,926,993
Contingencies (25%)				3,926,993
Subtotal				19,665,395
Present worths of maintenance brought back at year 15	0.315241705			6,199,353
Total present worths				6,199,353
Amortization factor				0.088827
Annual cost of structure and dune maintenance				550,670
Summary of Annual Costs				
Interest and Amortization				10,992,619
Initial and Periodic Beach Nourishment				972,977
Structure and Dune Maintenance				550,670
Total Annual Costs				12,516,265

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Appendix F: Preliminary Cost Estimate Spreadsheets - Timbalier Islands

Timbalier Islands: Alternative 1 - 5 year Return Period Design

Project Acreage	4,275 acres
Project Island(s) Length	18.6 miles
Island Restoration and Periodic Beach and Dune Nourishment	
Dune height	7 ft

COST ESTIMATE

First Costs

	Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction					
	Mobilization and Demobilization	L.S.		1,000,000	1,000,000
	Back Retention Dike	2,404,035	cu. yd.	4.00	9,616,142
	Sandfill				
	Dune	2,367,905	cu. yd.	4.00	9,471,618
	Beach Fill	4,965,533	cu. yd.	1.30	6,455,193
	Advanced Fill1	7,922,746	cu. yd.	1.30	10,299,569
	Back Barrier Berm	20,080,577	cu. yd.	1.30	26,104,750
	Confined Sand Platform Over Open Water	16,480,800	cu. yd.	1.30	21,425,040
	Subtotal	51,817,560	cu. yd.		84,372,313
	Vegetation				
	Aerial Planting	3,463	acre	150.00	519,413
	Hand Planting	128	acre	3,388.00	434,511
	Subtotal				953,924
	Engineering (20%) 2				17,065,247
	Contingencies (25%)				21,331,559
	Total First Cost				123,723,043

Annual Costs

	Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3					
	First Cost				123,723,043
	Amortization factor				0.088827
	Interest and Amortization				10,989,947
Periodic Beach Nourishment					
	Mobilization and Demobilization		L.S.	1,000,000	1,000,000
	Beach Fill	18,354,360	cu. yd.	1.30	23,860,669
	Subtotal				24,860,669
	Engineering (20%) 2				4,972,134
	Contingencies (25%)				6,215,167
	Total cost of one periodic nourishment				36,047,969
	Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			65,592,327
	Total present worths				65,592,327
	Amortization factor				0.088827
	Annual cost of initial and periodic nourishment				5,826,370
Periodic Structure and Dune Maintenance					
	Structure Maintenance		LF		
	Dune Maintenance	563,813	cu. yd.	4.00	2,255,252
	Engineering (20%) 2				451,050
	Contingencies (25%)				563,813
	Subtotal				3,270,115
	Present worths of maintenance brought back at years 5, 10, 15, 20, 25	1.819584502			5,950,250
	Total present worths				5,950,250
	Amortization factor				0.088827
	Annual cost of structure and dune maintenance				528,543
Summary of Annual Costs					
	Interest and Amortization				10,989,947
	Initial and Periodic Beach Nourishment				5,826,370
	Structure and Dune Maintenance				528,543
Total Annual Costs					17,344,859

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Timbalier Islands: Alternative 1 - 10 year Return Period Design

Total Acreage 4,275 acres
Total Island(s) Length 18.6 miles
Island Restoration and Periodic Beach and Dune Nourishment
Dune height 10.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	2,404,035	cu. yd.	4.00	9,616,142
Sandfill				
Dune	2,812,117	cu. yd.	4.00	11,248,469
Beach Fill	3,040,980	cu. yd.	1.30	3,953,274
Advanced Fill1	7,922,746	cu. yd.	1.30	10,299,569
Back Barrier Berm	22,624,761	cu. yd.	1.30	29,412,189
Confined Sand Platform Over Open Water	16,480,800	cu. yd.	1.30	21,425,040
Subtotal	52,881,403	cu. yd.		86,954,683
Vegetation				
Aerial Planting	3,390	acre	150.00	508,511
Hand Planting	167	acre	3,388.00	564,864
Subtotal				1,073,376
Engineering (20%) 2				17,605,612
Contingencies (25%)				22,007,015
Total First Cost				127,640,684

Annual Costs

Item	Quantity	Unit	Unit Cost	Cost
Interest and Amortization3				
First Cost				127,640,684
Amortization factor				0.088827
Interest and Amortization				11,337,939
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	18,354,360	cu. yd.	1.30	23,860,669
Subtotal				24,860,669
Engineering (25%) 2				6,215,167
Contingencies (25%)				6,215,167
Total cost of one periodic nourishment				37,291,003
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			67,854,131
Total present worths				67,854,131
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				6,027,279
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	1,662,347	cu. yd.	4.00	6,649,390
Engineering (25%) 2				1,662,347
Contingencies (25%)				1,662,347
Subtotal				9,974,085
Present worths of maintenance brought back at years 10, 20	0.677741695			6,759,853
Total present worths				6,759,853
Amortization factor				0.088827
Annual cost of structure and dune maintenance				600,457
Summary of Annual Costs				
Interest and Amortization				11,337,939
Initial and Periodic Beach Nourishment				6,027,279
Structure and Dune Maintenance				600,457
Total Annual Costs				17,965,675

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Timbalier Islands: Alternative 1 - 15 year Return Period Design

Total Acreage 4,275 acres
Total Island(s) Length 18.6 miles
Island Restoration and Periodic Beach and Dune Nourishment
Dune height 12.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	2,404,035	cu. yd.	4.00	9,616,142
Sandfill				
Dune	3,781,624	cu. yd.	4.00	15,126,498
Beach Fill	3,055,622	cu. yd.	1.30	3,972,309
Advanced Fill1	7,922,746	cu. yd.	1.30	10,299,569
Back Barrier Berm	22,321,805	cu. yd.	1.30	29,018,346
Confined Sand Platform Over Open Water	16,480,800	cu. yd.	1.30	21,425,040
Subtotal	53,562,597	cu. yd.		90,457,903
Vegetation				
Aerial Planting	3,347	acre	150.00	502,099
Hand Planting	188	acre	3,388.00	637,283
Subtotal				1,139,382
Engineering (20%) 2				18,319,457
Contingencies (25%)				22,899,321
Total First Cost				132,816,063

Annual Costs

Item	Quantity	Unit	Unit Cost	Cost
Interest and Amortization3				
First Cost				132,816,063
Amortization factor				0.088827
Interest and Amortization				11,797,652
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	18,354,360	cu. yd.	1.30	23,860,669
Subtotal				24,860,669
Engineering (25%) 2				6,215,167
Contingencies (25%)				6,215,167
Total cost of one periodic nourishment				37,291,003
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			67,854,131
Total present worths				67,854,131
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				6,027,279
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	2,521,496	cu. yd.	4.00	10,085,986
Engineering (25%) 2				2,521,496
Contingencies (25%)				2,521,496
Subtotal				15,128,979
Present worths of maintenance brought back at year 15	0.315241705			4,769,285
Total present worths				4769285.09
Amortization factor				0.088827
Annual cost of structure and dune maintenance				423641.2867
Summary of Annual Costs				
Interest and Amortization				11,797,652
Initial and Periodic Beach Nourishment				6,027,279
Structure and Dune Maintenance				423,641
Total Annual Costs				18,248,573

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Timbalier Islands: Alternative 1 - Revetment Option

Project Acreage	4,275 acres
Project Island(s) Length	18.6 miles
Revetment Option	
Dune height	+11.1 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Armor Stone	570,384	ton	35.00	19,963,433
Underlayer Stone	134,249	ton	35.00	4,698,710
Filter Cloth	5,306,358	sq. ft.	0.50	2,653,179
Toe Excavatrion	258,362	cu. yd.	2.00	516,724
Back Retention Dike	2,434,565	cu. yd.	4.00	9,738,260
Sandfill				
Dune	13,305,643	cu. yd.	4.00	53,222,572
Back Barrier Berm	26,594,393	cu. yd.	1.20	31,913,272
Confined Sand Platform Over Open Water	16,480,800	cu. yd.	1.20	19,776,960
Subtotal	56,380,836	cu. yd.		143,483,110
Vegetation				
Aerial Planting	3,535	acre	150.00	530,314
Hand Planting	740	acre	3,388.00	2,505,680
Subtotal				3,035,994
Engineering (20%) 2				29,303,821
Contingencies (25%)				36,629,776
Total First Cost				212,452,701

Annual Costs

Interest and Amortization2			
First Cost			212,452,701
Amortization factor			0.088827
Interest and Amortization			18,871,536
Periodic Structure and Dune Maintenance			
Structure and Dune Maintenance	2,595,246	LS	2,595,246
Engineering (20%) 1			519,049
Contingencies (25%)			648,812
Subtotal			3,763,107
Present worths of maintenance brought back at years 10, 15, 20, 25	1.139001305		4,286,184
Total present worths			4,286,184
Amortization factor			0.088827
Annual cost of structure and dune maintenance			380,729
Summary of Annual Costs			
Interest and Amortization			18,871,536
Structure and Dune Maintenance			380,729
Total Annual Costs			19,252,265

1 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

2 Amortization over 30-yr period at 8%.

** 60-month period of construction

Timbalier Islands: Alternative 1 - 5 year Return Period Design

Total Acreage 4,275 acres
Total Island(s) Length 18.6 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components
Dune height 7 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3,135	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cu. yd.	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	89,040	ton	35.00	3,116,400
Underlayer Stone	26,964	ton	35.00	943,740
Bedlayer	13,380	cu. yd.	78.00	1,043,640
Filter Cloth	460,350	sq. ft.	0.50	230,175
Revetment:				
Armor Stone	587,219	ton	35.00	20,552,673
Underlayer Stone	138,211	ton	35.00	4,837,397
Filter Cloth	5,462,980	sq. ft.	0.50	2,731,490
Toe Excavation	265,988	cy	2.00	531,976
Back Retention Dike	2,404,035	cu. yd.	4.00	9,616,142
Sandfill				
Dune	2,367,905	cu. yd.	4.00	9,471,618
Beach Fill	1,671,504	cu. yd.	1.30	2,172,955
Advanced Fill1	3,798,069	cu. yd.	1.30	4,937,490
Back Barrier Berm	20,080,577	cu. yd.	1.30	26,104,750
Confined Sand Platform Over Open Water	16,480,800	cu. yd.	1.30	21,425,040
Subtotal	44,398,855	cu. yd.		108,860,070
Vegetation				
Aerial Planting	3,463	acre	150.00	519,413
Hand Planting	128	acre	3,388.00	434,511
Subtotal				953,924
Engineering (20%) 2				21,962,799
Contingencies (25%)				27,453,498
Total First Cost				159,230,291

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				159,230,291
Amortization factor				0.088827
Interest and Amortization				14,143,949
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	1,737,775	cu. yd.	1.30	2,259,107
Subtotal				3,259,107
Engineering (20%) 2				814,777
Contingencies (25%)				814,777
Total cost of one periodic nourishment				4,888,661
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			8,895,332
Total present worths				8,895,332
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				790,146
Periodic Structure and Dune Maintenance				
Structure Maintenance	2,982,932	LS		2,982,932
Dune Maintenance	270,285	cu. yd.	4.00	1,081,140
Engineering (20%) 2				3,253,217
Contingencies (25%)				3,253,217
Subtotal				10,570,507
Present worths of maintenance brought back at years 5, 10, 15, 20, 25	1.819584502			19,233,930
Total present worths				19,233,930
Amortization factor				0.088827
Annual cost of structure and dune maintenance				1,708,492
Summary of Annual Costs				
Interest and Amortization				14,143,949
Initial and Periodic Beach Nourishment				790,146
Structure and Dune Maintenance				1,708,492
Total Annual Costs				16,642,587

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Timbalier Islands: Alternative 1 - 10 year Return Period Design

Total Acreage	4,275 acres
Total Island(s) Length	18.6 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components	
Dune height	10.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3,135	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cu. yd.	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	89,040	ton	35.00	3,116,400
Underlayer Stone	26,964	ton	35.00	943,740
Bedlayer	13,380	cu. yd.	78.00	1,043,640
Filter Cloth	460,350	sq. ft.	0.50	230,175
Revetment:				
Armor Stone	587,219	ton	35.00	20,552,673
Underlayer Stone	138,211	ton	35.00	4,837,397
Filter Cloth	5,462,980	sq. ft.	0.50	2,731,490
Toe Excavation	265,988	cy	2.00	531,976
Back Retention Dike	2,404,035	cu. yd.	4.00	9,616,142
Sandfill				
Dune	2,812,117	cu. yd.	4.00	11,248,469
Beach Fill	1,023,659	cu. yd.	1.30	1,330,756
Advanced Fill1	3,798,069	cu. yd.	1.30	4,937,490
Back Barrier Berm	22,624,761	cu. yd.	1.30	29,412,189
Confined Sand Platform Over Open Water	16,480,800	cu. yd.	1.30	21,425,040
Subtotal	46,739,405	cu. yd.		113,102,160
Vegetation				
Aerial Planting	3,390	acre	150.00	508,511
Hand Planting	167	acre	3,388.00	564,864
Subtotal				1,073,376
Engineering (20%) 2				22,835,107
Contingencies (25%)				28,543,884
Total First Cost				165,554,526

Annual Costs

Interest and Amortization3				
First Cost				165,554,526
Amortization factor				0.088827
Interest and Amortization				14,705,712
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	1,737,775	cu. yd.	1.30	2,259,107
Subtotal				3,259,107
Engineering (25%) 2				814,777
Contingencies (25%)				814,777
Total cost of one periodic nourishment				4,888,661
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			8,895,332
Total present worths				8,895,332
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				790,146
Periodic Structure and Dune Maintenance				
Structure Maintenance	5,965,864	LS		5,965,864
Dune Maintenance	796,909	cu. yd.	4.00	3,187,638
Engineering (25%) 2				6,762,773
Contingencies (25%)				6,762,773
Subtotal				22,679,048
Present worths of maintenance brought back at years 10 and 20	0.677741695			15,370,537
Total present worths				15,370,537
Amortization factor				0.088827
Annual cost of structure and dune maintenance				1,365,319
Summary of Annual Costs				
Interest and Amortization				14,705,712
Initial and Periodic Beach Nourishment				790,146
Structure and Dune Maintenance				1,365,319
Total Annual Costs				16,861,176

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Timbalier Islands: Alternative 1 - 15 year Return Period Design

Total Acreage 4,275 acres
Total Island(s) Length 18.6 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components
Dune height 12.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3,135	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cu. yd.	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	89,040	ton	35.00	3,116,400
Underlayer Stone	26,964	ton	35.00	943,740
Bedlayer	13,380	cu. yd.	78.00	1,043,640
Filter Cloth	460,350	sq. ft.	0.50	230,175
Revetment:				
Armor Stone	587,219	ton	35.00	20,552,673
Underlayer Stone	138,211	ton	35.00	4,837,397
Filter Cloth	5,462,980	sq. ft.	0.50	2,731,490
Toe Excavation	265,988	cy	2.00	531,976
Back Retention Dike	2,404,035	cu. yd.	4.00	9,616,142
Sandfill				
Dune	3,781,624	cu. yd.	4.00	15,126,498
Beach Fill	1,023,659	cu. yd.	1.30	1,330,756
Advanced Fill1	3,798,069	cu. yd.	1.30	4,937,490
Back Barrier Berm	22,321,805	cu. yd.	1.30	29,018,346
Confined Sand Platform Over Open Water	16,480,800	cu. yd.	1.30	21,425,040
Subtotal	47,405,957	cu. yd.		116,586,346
Vegetation				
Aerial Planting	3,347	acre	150.00	502,099
Hand Planting	188	acre	3,388.00	637,283
Subtotal				1,139,382
Engineering (20%) 2				23,545,146
Contingencies (25%)				29,431,432
Total First Cost				170,702,305

Annual Costs

Interest and Amortization3				
First Cost				170,702,305
Amortization factor				0.088827
Interest and Amortization				15,162,974
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	1,737,775	cu. yd.	1.30	2,259,107
Subtotal				3,259,107
Engineering (25%) 2				814,777
Contingencies (25%)				814,777
Total cost of one periodic nourishment				4,888,661
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			8,895,332
Total present worths				8,895,332
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				790,146
Periodic Structure and Dune Maintenance				
Structure Maintenance	8,948,796	LS		8,948,796
Dune Maintenance	1,208,775	cu. yd.	4.00	4,835,100
Engineering (25%) 2				10,157,571
Contingencies (25%)				10,157,571
Subtotal				34,099,039
Present worths of maintenance brought back at year 15	0.315242			10,749,449
Total present worths				10,749,449
Amortization factor				0.088827
Annual cost of structure and dune maintenance				954,841
Summary of Annual Costs				
Interest and Amortization				15,162,974
Initial and Periodic Beach Nourishment				790,146
Structure and Dune Maintenance				954,841
Total Annual Costs				16,907,961

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Timbalier Islands: Alternative 1 - Wave Absorbers

Project Length	20.1 miles
Number of Breakwaters	236

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Armor Stone	548,134	ton	35.00	19,184,676
Bed Layer Stone	40,592	cu. yd.	78.00	3,166,176
Filter Cloth	2,767,336	sq. ft.	0.50	1,383,668
Subtotal				24,734,520
Engineering (20%) 1				4,946,904
Contingencies (25%)				6,183,630
Total First Cost				35,865,054

Annual Costs

Item	Quantity	Unit	Cost
Interest and Amortization2			
First Cost			35,865,054
Amortization factor			0.088827
Interest and Amortization			3,185,785
Periodic Structure Maintenance			
Structure Maintenance	2,877,701	LS	2,877,701
Engineering (20%) 1			575,540
Contingencies (25%)			719,425
Subtotal			4,172,667
Present worths of maintenance brought back at years 10, 15, 20, 25	1.139001305		4,752,673
Total present worths			4,752,673
Amortization factor			0.088827
Annual cost of structure maintenance			422,166
Summary of Annual Costs			
Interest and Amortization			3,185,785
Structure Maintenance			422,166
Total Annual Costs			3,607,951

1 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

2 Amortization over 30-yr period at 8%.

** 60-month period of construction

Timbalier Islands: Alternative 2 - 5 year Return Period Design

Total Acreage	2,471 acres
Total Island(s) Length	16.7 miles
Island Restoration and Periodic Beach and Dune Nourishment	
Dune height	7 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	2,152,340	cu. yd.	4.00	8,609,361
Sandfill				
Dune	1,712,136	cu. yd.	4.00	6,848,545
Beach Fill	3,679,394	cu. yd.	1.30	4,783,212
Advanced Fill[1]	7,093,258	cu. yd.	1.30	9,221,235
Back Barrier Berm	14,519,454	cu. yd.	1.30	18,875,290
Confined Sand Platform Over Open Water	6,474,600	cu. yd.	1.30	8,416,980
Subtotal	33,478,842	cu. yd.		57,754,623
Vegetation				
Aerial Planting	1,717	acre	150.00	257,602
Hand Planting	121	acre	3,388.00	410,216
Subtotal				667,817
Engineering (20%)[2]				11,684,488
Contingencies (25%)				14,605,610
Total First Cost				84,712,538

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization[3]				
First Cost				84,712,538
Amortization factor				0.088827
Interest and Amortization				7,524,761
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	17,142,040	cu. yd.	1.30	22,284,652
Subtotal				23,284,652
Engineering (20%)[2]				4,656,930
Contingencies (25%)				5,821,163
Total cost of one periodic nourishment				33,762,745
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			61,434,168
Total present worths				61,434,168
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				5,457,013
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	504,783	cu. yd.	4.00	2,019,133
Engineering (20%)[2]				403,827
Contingencies (25%)				504,783
Subtotal				2,927,743
Present worths of maintenance brought back at years 5, 10, 15, 20, 25	1.819584502			5,327,277
Total present worths				5,327,277
Amortization factor				0.088827
Annual cost of structure and dune maintenance				473,206
Summary of Annual Costs				
Interest and Amortization				7,524,761
Initial and Periodic Beach Nourishment				5,457,013
Structure and Dune Maintenance				473,206
Total Annual Costs				13,454,979

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Timbalier Islands: Alternative 2 - 10 year Return Period Design

Total Acreage	2,471 acres
Total Island(s) Length	16.7 miles
Island Restoration and Periodic Beach and Dune Nourishment	
Dune height	10.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	2,152,340	cu. yd.	4.00	8,609,361
Sandfill				
Dune	3,287,370	cu. yd.	4.00	13,149,481
Beach Fill	3,137,365	cu. yd.	1.30	4,078,575
Advanced Fill1	7,093,258	cu. yd.	1.30	9,221,235
Back Barrier Berm	13,956,648	cu. yd.	1.30	18,143,642
Confined Sand Platform Over Open Water	6,474,600	cu. yd.	1.30	8,416,980
Subtotal	33,949,241	cu. yd.		62,619,274
Vegetation				
Aerial Planting	1,651	acre	150.00	247,594
Hand Planting	153	acre	3,388.00	519,048
Subtotal				766,643
Engineering (20%) 2				12,677,183
Contingencies (25%)				15,846,479
Total First Cost				91,909,579

Annual Costs

Interest and Amortization3				
First Cost				91,909,579
Amortization factor				0.088827
Interest and Amortization				8,164,052
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	17,142,040	cu. yd.	1.30	22,284,652
Subtotal				23,284,652
Engineering (25%) 2				5,821,163
Contingencies (25%)				5,821,163
Total cost of one periodic nourishment				34,926,978
Present worths of periodic nourishment brought back at years 5,10, 15, 20,25	1.819584502			63,552,587
Total present worths				63,552,587
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				5,645,186
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	1,488,305	cu. yd.	4.00	5,953,219
Engineering (25%) 2				1,488,305
Contingencies (25%)				1,488,305
Subtotal				8,929,828
Present worths of maintenance brought back at years 10, 20	0.677741695			6,052,117
Total present worths				6,052,117
Amortization factor				0.088827
Annual cost of structure and dune maintenance				537,591
Summary of Annual Costs				
Interest and Amortization				8,164,052
Initial and Periodic Beach Nourishment				5,645,186
Structure and Dune Maintenance				537,591
Total Annual Costs				14,346,829

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Timbalier Islands: Alternative 2 - 15 year Return Period Design

Total Acreage	2,471 acres
Total Island(s) Length	16.7 miles
Island Restoration and Periodic Beach and Dune Nourishment	
Dune height	12.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	2,152,340	cu. yd.	4.00	8,609,361
Sandfill				
Dune	4,410,537	cu. yd.	4.00	17,642,149
Beach Fill	3,704,664	cu. yd.	1.30	4,816,064
Advanced Fill1	7,093,258	cu. yd.	1.30	9,221,235
Back Barrier Berm	13,605,651	cu. yd.	1.30	17,687,346
Confined Sand Platform Over Open Water	6,474,600	cu. yd.	1.30	8,416,980
Subtotal	35,288,710	cu. yd.		67,393,134
Vegetation				
Aerial Planting	1,611	acre	150.00	241,664
Hand Planting	173	acre	3,388.00	586,022
Subtotal				827,686
Engineering (20%) 2				13,644,164
Contingencies (25%)				17,055,205
Total First Cost				98,920,190

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				98,920,190
Amortization factor				0.088827
Interest and Amortization				8,786,784
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	17,142,040	cu. yd.	1.30	22,284,652
Subtotal				23,284,652
Engineering (25%) 2				5,821,163
Contingencies (25%)				5,821,163
Total cost of one periodic nourishment				34,926,978
Present worths of periodic nourishment brought back at years 5,10, 15, 20,25	1.819584502			63,552,587
Total present worths				63,552,587
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				5,645,186
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	2,257,503	cu. yd.	4.00	9,030,013
Engineering (25%) 2				2,257,503
Contingencies (25%)				2,257,503
Subtotal				13,545,020
Present worths of maintenance brought back at year 15	0.315241705			4,269,955
Total present worths				4,269,955
Amortization factor				0.088827
Annual cost of structure and dune maintenance				379,287
Summary of Annual Costs				
Interest and Amortization				8,786,784
Initial and Periodic Beach Nourishment				5,645,186
Structure and Dune Maintenance				379,287
Total Annual Costs				14,811,257

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Timbalier Islands Alternative 2 - Revetment Option

Project Acreage	2,471 acres
Project Island(s) Length	16.7 miles
Revetment Option	
Dune height	+11.1 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Armor Stone	510,556	ton	35.00	17,869,452
Underlayer Stone	120,167	ton	35.00	4,205,859
Filter Cloth	4,749,770	sq. ft.	0.50	2,374,885
Toe Excavatrion	231,262	cu. yd.	2.00	462,524
Back Retention Dike	2,179,202	cu. yd.	4.00	8,716,806
Sandfill				
Dune	11,910,003	cu. yd.	4.00	47,640,013
Back Barrier Berm	12,861,736	cu. yd.	1.20	15,434,083
Confined Sand Platform Over Open Water	6,474,600	cu. yd.	1.20	7,769,520
Subtotal	31,246,340	cu. yd.		105,473,143
Vegetation				
Aerial Planting	1,868	acre	150.00	280,211
Hand Planting	603	acre	3,388.00	2,042,707
Subtotal				2,322,918
Engineering (20%) 2				21,559,212
Contingencies (25%)				26,949,015
Total First Cost				156,304,289

Annual Costs

Interest and Amortization2			
First Cost			156,304,289
Amortization factor			0.088827
Interest and Amortization			13,884,041
Periodic Structure and Dune Maintenance			
Structure and Dune Maintenance	2,323,029	LS	2,323,029
Engineering (20%) 1			464,606
Contingencies (25%)			580,757
Subtotal			3,368,392
Present worths of maintenance brought back at years 10, 15, 20, 25	1.139001305		3,836,603
Total present worths			3,836,603
Amortization factor			0.088827
Annual cost of structure and dune maintenance			340,794
Summary of Annual Costs			
Interest and Amortization			13,884,041
Structure and Dune Maintenance			340,794
Total Annual Costs			14,224,835

1 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

2 Amortization over 30-yr period at 8%.

** 60-month period of construction

Timbalier Islands: Alternative 2 - 5 year Return Period Design

Total Acreage 2,471 acres
Total Island(s) Length 16.7 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components
Dune height 7 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3,135	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cu. yd.	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	89,040	ton	35.00	3,116,400
Underlayer Stone	26,964	ton	35.00	943,740
Bedlayer	13,380	cu. yd.	78.00	1,043,640
Filter Cloth	460,350	sq. ft.	0.50	230,175
Revetment:				
Armor Stone	234,456	ton	35.00	8,205,961
Underlayer Stone	55,183	ton	35.00	1,931,403
Filter Cloth	2,181,176	sq. ft.	0.50	1,090,588
Toe Excavation	106,200	cy	2.00	212,399
Back Retention Dike	2,152,340	cu. yd.	4.00	8,609,361
Sandfill				
Dune	1,712,136	cu. yd.	4.00	6,848,545
Beach Fill	1,881,361	cu. yd.	1.30	2,445,769
Advanced Fill1	3,798,069	cu. yd.	1.30	4,937,490
Back Barrier Berm	14,519,454	cu. yd.	1.30	18,875,290
Confined Sand Platform Over Open Water	6,474,600	cu. yd.	1.30	8,416,980
Subtotal	28,385,620	cu. yd.		68,052,325
Vegetation				
Aerial Planting	1,717	acre	150.00	257,602
Hand Planting	121	acre	3,388.00	410,216
Subtotal				667,817
Engineering (20%) 2				13,744,028
Contingencies (25%)				17,180,036
Total First Cost				99,644,206

Annual Costs

Interest and Amortization3				
First Cost				99,644,206
Amortization factor				0.088827
Interest and Amortization				8,851,096
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	1,760,009	cu. yd.	1.30	2,288,012
Subtotal				3,288,012
Engineering (20%) 2				657,602
Contingencies (25%)				822,003
Total cost of one periodic nourishment				4,767,618
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			8,675,083
Total present worths				8,675,083
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				770,582
Periodic Structure and Dune Maintenance				
Structure Maintenance	1,377,860	LS		1,377,860
Dune Maintenance	270,285	cu. yd.	4.00	1,081,140
Engineering (20%) 2				1,594,088
Contingencies (25%)				1,648,145
Subtotal				5,701,232
Present worths of maintenance brought back at years 5, 10, 15, 20, 25	1.819584502			10,373,874
Total present worths				10,373,874
Amortization factor				0.088827
Annual cost of structure and dune maintenance				921,480
Summary of Annual Costs				
Interest and Amortization				8,851,096
Initial and Periodic Beach Nourishment				770,582
Structure and Dune Maintenance				921,480
Total Annual Costs				10,543,158

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Timbalier Islands: Alternative 2 - 10 year Return Period Design

Total Acreage 2,471 acres
Total Island(s) Length 16.7 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components
Dune height 10.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3,135	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cu. yd.	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	89,040	ton	35.00	3,116,400
Underlayer Stone	26,964	ton	35.00	943,740
Bedlayer	13,380	cu. yd.	78.00	1,043,640
Filter Cloth	460,350	sq. ft.	0.50	230,175
Revetment:				
Armor Stone	234,456	ton	35.00	8,205,961
Underlayer Stone	55,183	ton	35.00	1,931,403
Filter Cloth	2,181,176	sq. ft.	0.50	1,090,588
Toe Excavation	106,200	cy	2.00	212,399
Back Retention Dike	2,152,340	cu. yd.	4.00	8,609,361
Sandfill				
Dune	2,098,116	cu. yd.	4.00	8,392,463
Beach Fill	2,194,465	cu. yd.	1.30	2,852,804
Advanced Fill1	3,798,069	cu. yd.	1.30	4,937,490
Back Barrier Berm	13,956,648	cu. yd.	1.30	18,143,642
Confined Sand Platform Over Open Water	6,474,600	cu. yd.	1.30	8,416,980
Subtotal	28,521,897	cu. yd.		69,271,631
Vegetation				
Aerial Planting	1,651	acre	150.00	247,594
Hand Planting	153	acre	3,388.00	519,048
Subtotal				766,643
Engineering (20%) 2				14,007,655
Contingencies (25%)				17,509,568
Total First Cost				101,555,496

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				101,555,496
Amortization factor				0.088827
Interest and Amortization				9,020,870
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	1,760,009	cu. yd.	1.30	2,288,012
Subtotal				3,288,012
Engineering (25%) 2				822,003
Contingencies (25%)				822,003
Total cost of one periodic nourishment				4,932,018
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			8,974,224
Total present worths				8,974,224
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				797,153
Periodic Structure and Dune Maintenance				
Structure Maintenance	2,755,719	LS		2,755,719
Dune Maintenance	796,909	cu. yd.	4.00	3,187,638
Engineering (25%) 2				3,552,628
Contingencies (25%)				3,552,628
Subtotal				13,048,614
Present worths of maintenance brought back at years 10 and 20	0.677741695			8,843,589
Total present worths				8,843,589
Amortization factor				0.088827
Annual cost of structure and dune maintenance				785,550
Summary of Annual Costs				
Interest and Amortization				9,020,870
Initial and Periodic Beach Nourishment				797,153
Structure and Dune Maintenance				785,550
Total Annual Costs				10,603,573

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Timbalier Islands: Alternative 2 - 15 year Return Period Design

Total Acreage 2,471 acres
Total Island(s) Length 16.7 miles
Island Restoration and Periodic Beach and Dune Nourishment with Structural Components
Dune height 12.3 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Groin:				
Armor Stone	3,135	ton	35.00	109,711
Underlayer Stone	192	ton	35.00	6,713
Bedlayer	220	cu. yd.	78.00	17,160
Filter Cloth	22,000	sq. ft.	0.50	11,000
Breakwaters:				
Armor Stone	89,040	ton	35.00	3,116,400
Underlayer Stone	26,964	ton	35.00	943,740
Bedlayer	13,380	cu. yd.	78.00	1,043,640
Filter Cloth	460,350	sq. ft.	0.50	230,175
Revetment:				
Armor Stone	234,456	ton	35.00	8,205,961
Underlayer Stone	55,183	ton	35.00	1,931,403
Filter Cloth	2,181,176	sq. ft.	0.50	1,090,588
Toe Excavation	106,200	cy	2.00	212,399
Back Retention Dike	2,152,340	cu. yd.	4.00	8,609,361
Sandfill				
Dune	4,410,537	cu. yd.	4.00	17,642,149
Beach Fill	1,894,282	cu. yd.	1.30	2,462,567
Advanced Fill1	3,798,069	cu. yd.	1.30	4,937,490
Back Barrier Berm	13,605,651	cu. yd.	1.30	17,687,346
Confined Sand Platform Over Open Water	6,474,600	cu. yd.	1.30	8,416,980
Subtotal	30,183,139	cu. yd.		77,674,783
Vegetation				
Aerial Planting	1,611	acre	150.00	241,664
Hand Planting	173	acre	3,388.00	586,022
Subtotal				827,686
Engineering (20%) 2				15,700,494
Contingencies (25%)				19,625,617
Total First Cost				113,828,580

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				113,828,580
Amortization factor				0.088827
Interest and Amortization				10,111,051
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	1,760,009	cu. yd.	1.30	2,288,012
Subtotal				3,288,012
Engineering (25%) 2				822,003
Contingencies (25%)				822,003
Total cost of one periodic nourishment				4,932,018
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			8,974,224
Total present worths				8,974,224
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				797,153
Periodic Structure and Dune Maintenance				
Structure Maintenance	4,681,680	LS		4,681,680
Dune Maintenance	1,208,775	cu. yd.	4.00	4,835,100
Engineering (25%) 2				5,890,455
Contingencies (25%)				5,890,455
Subtotal				21,297,691
Present worths of maintenance brought back at year 15	0.315241705			6,713,920
Total present worths				6,713,920
Amortization factor				0.088827
Annual cost of structure and dune maintenance				596,377
Summary of Annual Costs				
Interest and Amortization				10,111,051
Initial and Periodic Beach Nourishment				797,153
Structure and Dune Maintenance				596,377
Total Annual Costs				11,504,582

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Appendix G: Preliminary Cost Estimate Spreadsheets - Caminada-Moreau Headland

Caminada-Moreau Headland: Alternative 1 - Revetment Option

Project Acreage	510 acres
Project Island(s) Length	11.6 miles
Revetment Option	
Dune height	+13.5 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Armor Stone	394,373	ton	35.00	13,803,045
Underlayer Stone	91,735	ton	35.00	3,210,708
Filter Cloth	3,760,013	sq. ft.	0.50	1,880,007
Toe Excavatrion	159,219	cu. yd.	2.00	318,438
Back Retention Dike	1,500,331	cu. yd.	4.00	6,001,324
Sandfill				
Dune	9,945,051	cu. yd.	4.00	39,780,205
Subtotal	9,945,051	cu. yd.		65,993,727
Vegetation				
Hand Planting	510	acre	3,388.00	1,727,880
Subtotal				1,727,880
Engineering (20%) 2				13,544,321
Contingencies (25%)				16,930,402
Total First Cost				98,196,329

Annual Costs

Interest and Amortization2			
First Cost			98,196,329
Amortization factor			0.088827
Interest and Amortization			8,722,485
Periodic Structure and Dune Maintenance			
Structure and Dune Maintenance	2,760,609	LS	2,760,609
Engineering (25%) 1			607,334
Contingencies (20%)			690,152
Subtotal			4,058,095
Present worths of maintenance brought back at years 10, 15, 20, 25	1.139001305		4,622,176
Total present worths			4,622,176
Amortization factor			0.088827
Annual cost of structure and dune maintenance			410,574
Summary of Annual Costs			
Interest and Amortization			8,722,485
Structure and Dune Maintenance			410,574
Total Annual Costs			9,133,059

1 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

2 Amortization over 30-yr period at 8%.

** 60-month period of construction

Caminada-Moreau Headland: Alternative 1 - 5 year Return Period Design

Project Acreage	590 acres
Project Island(s) Length	11.6 miles
Shoreline Restoration and Periodic Beach and Dune Nourishment	
Dune height	8.7 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	1,499,009	cu. yd.	4.00	5,996,034
Sandfill				
Dune	482,869	cu. yd.	4.00	1,931,476
Beach Fill	1,576,865	cu. yd.	1.80	2,838,357
Advanced Fill1	22,704,999	cu. yd.	1.80	40,868,998
Subtotal	24,764,733	cu. yd.		52,634,866
Vegetation				
Hand Planting	590	acre	3,388.00	1,998,920
Subtotal				1,998,920
Engineering (20%) 2				10,926,757
Contingencies (25%)				13,658,446
Total First Cost				79,218,989

Annual Costs

Interest and Amortization3				
First Cost				79,218,989
Amortization factor				0.088827
Interest and Amortization				7,036,785
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	112,212,823	cu. yd.	1.80	201,983,082
Subtotal				202,983,082
Engineering (25%) 2				50,745,771
Contingencies (25%)				50,745,771
Total cost of one periodic nourishment				304,474,623
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			554,017,306
Total present worths				554,017,306
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				49,211,695
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	351,559	cu. yd.	4.00	1,406,236
Engineering (25%) 2				351,559
Contingencies (25%)				351,559
Subtotal				2,109,354
Present worths of maintenance brought back at years 5, 10, 15, 20, 25	1.819584502			3,838,148
Total present worths				3,838,148
Amortization factor				0.088827
Annual cost of structure and dune maintenance				340,931
Summary of Annual Costs				
Interest and Amortization				7,036,785
Initial and Periodic Beach Nourishment				49,211,695
Structure and Dune Maintenance				340,931
Total Annual Costs				56,589,412

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Caminada-Moreau Headland: Alternative 1 - 10 year Return Period Design

Project Acreage 590 acres
Project Island(s) Length 11.6 miles
Shoreline Restoration and Periodic Beach and Dune Nourishment
Dune height 10.6 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	1,499,009	cu. yd.	4.00	5,996,034
Sandfill				
Dune	745,161	cu. yd.	4.00	2,980,646
Beach Fill	1,980,450	cu. yd.	1.80	3,564,809
Advanced Fill1	22,704,999	cu. yd.	1.80	40,868,998
Subtotal	25,430,610	cu. yd.		54,410,487
Vegetation				
Hand Planting	590	acre	3,388.00	1,998,920
Subtotal				1,998,920
Engineering (20%) 2				11,281,881
Contingencies (25%)				14,102,352
Total First Cost				81,793,641

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				81,793,641
Amortization factor				0.088827
Interest and Amortization				7,265,484
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	112,212,823	cu. yd.	1.80	201,983,082
Subtotal				202,983,082
Engineering (25%) 2				50,745,771
Contingencies (25%)				50,745,771
Total cost of one periodic nourishment				304,474,623
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			554,017,306
Total present worths				554,017,306
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				49,211,695
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	1,036,538	cu. yd.	4.00	4,146,150
Engineering (25%) 2				1,036,538
Contingencies (25%)				1,036,538
Subtotal				6,219,225
Present worths of maintenance brought back at years 10, 20	0.677741695			4,215,028
Total present worths				4,215,028
Amortization factor				0.088827
Annual cost of structure and dune maintenance				374,408
Summary of Annual Costs				
Interest and Amortization				7,265,484
Initial and Periodic Beach Nourishment				49,211,695
Structure and Dune Maintenance				374,408
Total Annual Costs				56,851,587

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Caminada-Moreau Headland: Alternative 1 - 15 year Return Period Design

Project Acreage	590 acres
Project Island(s) Length	11.6 miles
Shoreline Restoration and Periodic Beach and Dune Nourishment	
Dune height	11.6 ft

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Back Retention Dike	1,499,009	cu. yd.	4.00	5,996,034
Sandfill				
Dune	878,948	cu. yd.	4.00	3,515,793
Beach Fill	2,256,008	cu. yd.	1.80	4,060,814
Advanced Fill1	22,704,999	cu. yd.	1.80	40,868,998
Subtotal	25,839,955	cu. yd.		55,441,639
Vegetation				
Hand Planting	590	acre	3,388.00	1,998,920
Subtotal				1,998,920
Engineering (20%) 2				11,488,112
Contingencies (25%)				14,360,140
Total First Cost				83,288,811

Annual Costs

	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				83,288,811
Amortization factor				0.088827
Interest and Amortization				7,398,295
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	1,000,000	1,000,000
Beach Fill	112,212,823	cu. yd.	1.80	201,983,082
Subtotal				202,983,082
Engineering (25%) 2				50,745,771
Contingencies (25%)				50,745,771
Total cost of one periodic nourishment				304,474,623
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			554,017,306
Total present worths				554,017,306
Amortization factor				0.088827
Annual cost of initial and periodic nourishment				49,211,695
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	1,499,009	cu. yd.	4.00	5,996,034
Engineering (25%) 2				1,499,009
Contingencies (25%)				1,499,009
Subtotal				8,994,051
Present worths of maintenance brought back at year 15	0.315241705			2,835,300
Total present worths				2,835,300
Amortization factor				0.088827
Annual cost of structure and dune maintenance				251,851
Summary of Annual Costs				
Interest and Amortization				7,398,295
Initial and Periodic Beach Nourishment				49,211,695
Structure and Dune Maintenance				251,851
Total Annual Costs				56,861,842

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

Appendix H: Preliminary Cost Estimate Spreadsheets - Plaquemines Shoreline

Plaquemines: Alternative 1 - 5 year Return Period Design

Project Acreage	6,968 acres
Project Island(s) Length	31.3 miles
Island Restoration and Periodic Beach and Dune Nourishment	
Dune height	+8.7 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		2,000,000	2,000,000
Back Retention Dike	3,317,816	cu. yd.	4.00	13,271,265
Sandfill				
Dune	4,069,847	cu. yd.	4.00	16,279,389
Beach Fill	11,303,076	cu. yd.	1.20	13,563,691
Advanced Fill1	34,748,884	cu. yd.	1.20	41,698,661
Back Barrier Berm	44,176,342	cu. yd.	1.20	53,011,610
Confined Sand Platform Over Open Water	16,873,200	cu. yd.	1.20	20,247,840
Subtotal	111,171,349	cu. yd.		160,072,456
Vegetation				
Aerial Planting	5,581	acre	150.00	837,205
Hand Planting	244	acre	3,388.00	826,265
Subtotal				1,663,471
Engineering (20%) 2				32,347,185
Contingencies (25%)				40,433,982
Total First Cost				234,517,093

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				234,517,093
Amortization factor				0.088827
Interest and Amortization				20,831,450
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	2,000,000	2,000,000
Beach Fill	81,774,891	cu. yd.	1.20	98,129,869
Subtotal				100,129,869
Engineering (25%) 2				25,032,467
Contingencies (25%)				25,032,467
Total cost of one periodic nourishment				150,194,804
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			273,292,138
Total present worths				273,292,138
Amortization factor				0.088827
Annual cost periodic nourishment				24,275,721
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	939,688	cu. yd.	4.00	3,758,753
Engineering (25%) 2				939,688
Contingencies (25%)				939,688
Subtotal				5,638,129
Present worths of maintenance brought back at years 5, 10, 15, 20, 25	1.819584502			10,259,052
Total present worths				10,259,052
Amortization factor				0.088827
Annual cost of structure and dune maintenance				911,281
Summary of Annual Costs				
Interest and Amortization				20,831,450
Periodic Beach Nourishment				24,275,721
Structure and Dune Maintenance				911,281
Total Annual Costs				46,018,451

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

** 24-month period of construction

Plaquemines: Alternative 1 - 10 year Return Period Design

Project Acreage 6,968 acres
Project Island(s) Length 31.3 miles
Island Restoration and Periodic Beach and Dune Nourishment
Dune height +10.6 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		2,000,000	2,000,000
Back Retention Dike	3,317,816	cu. yd.	4.00	13,271,265
Sandfill				
Dune	5,700,058	cu. yd.	4.00	22,800,233
Beach Fill	11,189,712	cu. yd.	1.20	13,427,654
Advanced Fill1	34,748,884	cu. yd.	1.20	41,698,661
Back Barrier Berm	43,668,567	cu. yd.	1.20	52,402,281
Confined Sand Platform Over Open Water	16,873,200	cu. yd.	1.20	20,247,840
Subtotal	112,180,421	cu. yd.		165,847,934
Vegetation				
Aerial Planting	5,512	acre	150.00	826,753
Hand Planting	279	acre	3,388.00	944,303
Subtotal				1,771,057
Engineering (20%) 2				33,523,798
Contingencies (25%)				41,904,748
Total First Cost				243,047,536

Annual Costs

Interest and Amortization3				
First Cost				243,047,536
Amortization factor				0.088827
Interest and Amortization				21,589,184
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	2,000,000	2,000,000
Beach Fill	81,774,891	cu. yd.	1.20	98,129,869
Subtotal				100,129,869
Engineering (25%) 2				25,032,467
Contingencies (25%)				25,032,467
Total cost of one periodic nourishment				150,194,804
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			273,292,138
Total present worths				273,292,138
Amortization factor				0.088827
Annual cost periodic nourishment				24,275,721
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	2,773,385	cu. yd.	4.00	11,093,540
Engineering (25%) 2				2,773,385
Contingencies (25%)				2,773,385
Subtotal				16,640,311
Present worths of maintenance brought back at years 10 and 20	0.677741695			11,277,832
Total present worths				11,277,832
Amortization factor				0.088827
Annual cost of structure and dune maintenance				1,001,776
Summary of Annual Costs				
Interest and Amortization				21,589,184
Periodic Beach Nourishment				24,275,721
Structure and Dune Maintenance				1,001,776
Total Annual Costs				46,866,680

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

** 24-month period of construction

Plaquemines: Alternative 1 - 15 year Return Period Design

Project Acreage	6,968 acres
Project Island(s) Length	31.3 miles
Island Restoration and Periodic Beach and Dune Nourishment	
Dune height	+11.6 ft msl

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		2,000,000	2,000,000
Back Retention Dike	3,317,816	cu. yd.	4.00	13,271,265
Sandfill				
Dune	6,628,670	cu. yd.	4.00	26,514,681
Beach Fill	11,151,763	cu. yd.	1.20	13,382,115
Advanced Fill1	34,748,884	cu. yd.	1.20	41,698,661
Back Barrier Berm	43,398,294	cu. yd.	1.20	52,077,952
Confined Sand Platform Over Open Water	16,873,200	cu. yd.	1.20	20,247,840
Subtotal	112,800,811	cu. yd.		169,192,514
Vegetation				
Aerial Planting	5,477	acre	150.00	821,527
Hand Planting	293	acre	3,388.00	991,519
Subtotal				1,813,046
Engineering (20%) 2				34,201,112
Contingencies (25%)				42,751,390
Total First Cost				247,958,062

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				247,958,062
Amortization factor				0.088827
Interest and Amortization				22,025,371
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	2,000,000	2,000,000
Beach Fill	81,774,891	cu. yd.	1.20	98,129,869
Subtotal				100,129,869
Engineering (25%) 2				25,032,467
Contingencies (25%)				25,032,467
Total cost of one periodic nourishment				150,194,804
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			273,292,138
Total present worths				273,292,138
Amortization factor				0.088827
Annual cost periodic nourishment				24,275,721
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	4,202,494	cu. yd.	4.00	16,809,977
Engineering (25%) 2				4,202,494
Contingencies (25%)				4,202,494
Subtotal				25,214,965
Present worths of maintenance brought back at year 15	0.315241705			7,948,808
Total present worths				7,948,808
Amortization factor				0.088827
Annual cost of structure and dune maintenance				706,069
Summary of Annual Costs				
Interest and Amortization				22,025,371
Periodic Beach Nourishment				24,275,721
Structure and Dune Maintenance				706,069
Total Annual Costs				47,007,160

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

** 24-month period of construction

Plaquemines: Alternative 1 - Revetment Option

Project Acreage	6,968 acres
Project Island(s) Length	31.6 miles
Revetment Option	
Dune height	+13.5 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Armor Stone	1,073,484	ton	35.00	37,571,926
Underlayer Stone	249,702	ton	35.00	8,739,557
Filter Cloth	10,234,766	sq. ft.	0.50	5,117,383
Toe Excavatrion	433,394	cu. yd.	2.00	866,788
Back Retention Dike	4,083,905	cu. yd.	4.00	16,335,620
Sandfill				
Dune	27,070,456	cu. yd.	4.00	108,281,824
Back Barrier Berm	44,606,244	cu. yd.	1.20	53,527,493
Confined Sand Platform Over Open Water	16,794,720	cu. yd.	1.20	20,153,664
Subtotal	88,471,420	cu. yd.		251,594,255
Vegetation				
Aerial Planting	5,763	acre	150.00	864,380
Hand Planting	1,205	acre	3,388.00	4,084,112
Subtotal				4,948,492
Engineering (20%) 2				51,308,549
Contingencies (25%)				64,135,687
Total First Cost				371,986,983

Annual Costs

Interest and Amortization2			
First Cost			371,986,983
Amortization factor			0.088827
Interest and Amortization			33,042,488
Periodic Structure and Dune Maintenance			
Structure and Dune Maintenance	7,514,385	LS	7,514,385
Engineering (20%) 1			1,502,877
Contingencies (25%)			1,878,596
Subtotal			10,895,859
Present worths of maintenance brought back at years 10, 15, 20, 25	1.139001305		12,410,397
Total present worths			12,410,397
Amortization factor			0.088827
Annual cost of structure and dune maintenance			1,102,378
Summary of Annual Costs			
Interest and Amortization			33,042,488
Structure and Dune Maintenance			1,102,378
Total Annual Costs			34,144,866

1 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

2 Amortization over 30-yr period at 8%.

** 60-month period of construction

Plaquemines: Alternative 1 - Wave Absorbers

Project Length	14.5 miles
Number of Breakwaters	177

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Armor Stone	411,100	ton	35.00	14,388,507
Bed Layer Stone	30,444	cu. yd.	78.00	2,374,632
Filter Cloth	2,075,502	sq. ft.	0.50	1,037,751
Subtotal				18,800,890
Engineering (20%) 1				3,760,178
Contingencies (25%)				4,700,223
Total First Cost				27,261,291

Annual Costs

Item	Quantity	Unit	Cost
Interest and Amortization2			
First Cost			27,261,291
Amortization factor			0.088827
Interest and Amortization			2,421,539
Periodic Structure Maintenance			
Structure Maintenance	2,158,276	LS	2,158,276
Engineering (20%) 1			431,655
Contingencies (25%)			539,569
Subtotal			3,129,500
Present worths of maintenance brought back at years 10, 15, 20, 25	1.139001305		3,564,505
Total present worths			3,564,505
Amortization factor			0.088827
Annual cost of structure maintenance			316,624
Summary of Annual Costs			
Interest and Amortization			2,421,539
Structure Maintenance			316,624
Total Annual Costs			2,738,163

1 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

2 Amortization over 30-yr period at 8%.

** 60-month period of construction

Plaquemines: Alternative 2 - 5 year Return Period Design

Project Acreage 3,978 acres
Project Island(s) Length 28.9 miles
Island Restoration and Periodic Beach and Dune Nourishment
Dune height +8.7 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		2,000,000	2,000,000
Back Retention Dike	3,600,271	cu. yd.	4.00	14,401,083
Sandfill				
Dune	3,705,262	cu. yd.	4.00	14,821,046
Beach Fill	10,194,733	cu. yd.	1.20	12,233,679
Advanced Fill1	32,368,909	cu. yd.	1.20	38,842,691
Back Barrier Berm	21,315,781	cu. yd.	1.20	25,578,937
Confined Sand Platform Over Open Water	1,726,560	cu. yd.	1.20	2,071,872
Subtotal	69,311,244	cu. yd.		109,949,308
Vegetation				
Aerial Planting	2,709	acre	150.00	406,353
Hand Planting	223	acre	3,388.00	754,738
Subtotal				1,161,091
Engineering (20%) 2				22,222,080
Contingencies (25%)				27,777,600
Total First Cost				161,110,079

Annual Costs

Interest and Amortization3				
First Cost				161,110,079
Amortization factor				0.088827
Interest and Amortization				14,310,925
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	2,000,000	2,000,000
Beach Fill	76,174,073	cu. yd.	1.20	91,408,888
Subtotal				93,408,888
Engineering (25%) 2				23,352,222
Contingencies (25%)				23,352,222
Total cost of one periodic nourishment				140,113,332
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			254,948,047
Total present worths				254,948,047
Amortization factor				0.088827
Annual cost periodic nourishment				22,646,270
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	875,328	cu. yd.	4.00	3,501,313
Engineering (25%) 2				875,328
Contingencies (25%)				875,328
Subtotal				5,251,969
Present worths of maintenance brought back at years 5, 10, 15, 20, 25	1.819584502			9,556,402
Total present worths				9,556,402
Amortization factor				0.088827
Annual cost of structure and dune maintenance				848,867
Summary of Annual Costs				
Interest and Amortization				14,310,925
Periodic Beach Nourishment				22,646,270
Structure and Dune Maintenance				848,867
Total Annual Costs				37,806,062

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

** 24-month period of construction

Plaquemines: Alternative 2 - 10 year Return Period Design

Project Acreage	3,978 acres
Project Island(s) Length	28.9 miles
Island Restoration and Periodic Beach and Dune Nourishment	
Dune height	+10.6 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		2,000,000	2,000,000
Back Retention Dike	3,600,271	cu. yd.	4.00	14,401,083
Sandfill				
Dune	5,168,522	cu. yd.	4.00	20,674,088
Beach Fill	10,165,130	cu. yd.	1.20	12,198,155
Advanced Fill1	32,368,909	cu. yd.	1.20	38,842,691
Back Barrier Berm	20,829,365	cu. yd.	1.20	24,995,238
Confined Sand Platform Over Open Water	1,726,560	cu. yd.	1.20	2,071,872
Subtotal	73,858,757	cu. yd.		115,183,128
Vegetation				
Aerial Planting	2,649	acre	150.00	397,402
Hand Planting	251	acre	3,388.00	849,080
Subtotal				1,246,482
Engineering (20%) 2				23,285,922
Contingencies (25%)				29,107,403
Total First Cost				168,822,935

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				168,822,935
Amortization factor				0.088827
Interest and Amortization				14,996,035
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	2,000,000	2,000,000
Beach Fill	76,174,073	cu. yd.	1.20	91,408,888
Subtotal				93,408,888
Engineering (25%) 2				23,352,222
Contingencies (25%)				23,352,222
Total cost of one periodic nourishment				140,113,332
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			254,948,047
Total present worths				254,948,047
Amortization factor				0.088827
Annual cost periodic nourishment				22,646,270
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	2,583,434	cu. yd.	4.00	10,333,736
Engineering (25%) 2				2,583,434
Contingencies (25%)				2,583,434
Subtotal				15,500,604
Present worths of maintenance brought back at years 10 and 20	0.677741695			10,505,406
Total present worths				10,505,406
Amortization factor				0.088827
Annual cost of structure and dune maintenance				933,164
Summary of Annual Costs				
Interest and Amortization				14,996,035
Periodic Beach Nourishment				22,646,270
Structure and Dune Maintenance				933,164
Total Annual Costs				38,575,469

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

** 24-month period of construction

Plaquemines: Alternative 2 - 15 year Return Period Design

Project Acreage	3,978 acres
Project Island(s) Length	28.9 miles
Island Restoration and Periodic Beach and Dune Nourishment	
Dune height	+11.6 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		2,000,000	2,000,000
Back Retention Dike	3,600,271	cu. yd.	4.00	14,401,083
Sandfill				
Dune	6,010,342	cu. yd.	4.00	24,041,366
Beach Fill	10,175,303	cu. yd.	1.20	12,210,363
Advanced Fill1	32,368,909	cu. yd.	1.20	38,842,691
Back Barrier Berm	20,567,709	cu. yd.	1.20	24,681,251
Confined Sand Platform Over Open Water	1,726,560	cu. yd.	1.20	2,071,872
Subtotal	70,848,822	cu. yd.		118,248,626
Vegetation				
Aerial Planting	2,610	acre	150.00	391,435
Hand Planting	267	acre	3,388.00	902,990
Subtotal				1,294,425
Engineering (20%) 2				23,908,610
Contingencies (25%)				29,885,763
Total First Cost				173,337,425

Annual Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Interest and Amortization3				
First Cost				173,337,425
Amortization factor				0.088827
Interest and Amortization				15,397,043
Periodic Beach Nourishment				
Mobilization and Demobilization		L.S.	2,000,000	2,000,000
Beach Fill	76,174,073	cu. yd.	1.20	91,408,888
Subtotal				93,408,888
Engineering (25%) 2				23,352,222
Contingencies (25%)				23,352,222
Total cost of one periodic nourishment				140,113,332
Present worths of periodic nourishment brought back at years 5, 10, 15, 20, 25	1.819584502			254,948,047
Total present worths				254,948,047
Amortization factor				0.088827
Annual cost periodic nourishment				22,646,270
Periodic Structure and Dune Maintenance				
Structure Maintenance		LF		
Dune Maintenance	3,914,662	cu. yd.	4.00	15,658,650
Engineering (25%) 2				3,914,662
Contingencies (25%)				3,914,662
Subtotal				23,487,975
Present worths of maintenance brought back at year 15	0.315241705			7,404,389
Total present worths				7,404,389
Amortization factor				0.088827
Annual cost of structure and dune maintenance				657,710
Summary of Annual Costs				
Interest and Amortization				15,397,043
Periodic Beach Nourishment				22,646,270
Structure and Dune Maintenance				657,710
Total Annual Costs				38,701,023

1 Sand added to account for losses between nourishment cycle.

2 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

3 Amortization over 30-yr period at 8%.

** 24-month period of construction

Plaquemines: Alternative 2 - Revetment Option

Project Acreage	3,978 acres
Project Island(s) Length	29.7 miles
Revetment Option	
Dune height	+13.5 ft MSL

COST ESTIMATE

First Costs

Item	Quantity	Unit	Unit Cost ($)	Cost ($)
Construction**				
Mobilization and Demobilization	L.S.		1,000,000	1,000,000
Structural				
Armor Stone	1,008,510	ton	35.00	35,297,865
Underlayer Stone	234,588	ton	35.00	8,210,590
Filter Cloth	9,615,301	sq. ft.	0.50	4,807,651
Toe Excavatrion	407,163	cu. yd.	2.00	814,325
Back Retention Dike	3,836,725	cu. yd.	4.00	15,346,898
Sandfill				
Dune	25,432,002	cu. yd.	4.00	101,728,010
Back Barrier Berm	22,644,505	cu. yd.	1.20	27,173,406
Confined Sand Platform Over Open Water	1,726,560	cu. yd.	1.20	2,071,872
Subtotal	49,803,067	cu. yd.		196,450,617
Vegetation				
Aerial Planting	3,007	acre	150.00	451,105
Hand Planting	971	acre	3,388.00	3,288,501
Subtotal				3,739,606
Engineering (20%) 2				40,038,045
Contingencies (25%)				50,047,556
Total First Cost				290,275,824

Annual Costs

Item	Quantity	Unit	Cost
Interest and Amortization2			
First Cost			290,275,824
Amortization factor			0.088827
Interest and Amortization			25,784,331
Periodic Structure and Dune Maintenance			
Structure and Dune Maintenance	7,059,573	LS	7,059,573
Engineering (20%) 1			1,411,915
Contingencies (25%)			1,764,893
Subtotal			10,236,381
Present worths of maintenance brought back at years 10, 15, 20, 25	1.139001305		11,659,251
Total present worths			11,659,251
Amortization factor			0.088827
Annual cost of structure and dune maintenance			1,035,656
Summary of Annual Costs			
Interest and Amortization			25,784,331
Structure and Dune Maintenance			1,035,656
Total Annual Costs			26,819,987

1 Includes design, surveys, geotechnical investigation, construction administration and inspection, rights-of-way, and permitting.

2 Amortization over 30-yr period at 8%.

** 60-month period of construction